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The Way Forwards for 3D Mapping at National Mapping and Cadastral Agencies

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Abstract

Three dimensional (3D) geospatial data has been gaining increasing traction in recent years, with research identifying existing and potential applications that range from archaeology and architecture to work that underpins government level policies on housing, climate change and improved quality of life. Standards such as CityGML and CityJSON have helped to increase uptake. However, while there has been extensive focus on issues such as feature extraction from data, and various applications of 3D city models, there has been less focus on the challenges faced by those charged with producing such data at national scale in order to meet policy demand - i.e. the National Mapping and Cadastral Agencies (NMCAs). This paper explores NMCA understanding of the users and applications of 3D data in comparison to those identified in literature and reviews the challenges NMCAs face in meeting current and future demand, tracking these over time to help identify major long-term blockers to national 3D rollout.

1. Introduction

In recent years, there has been an ever-growing understanding of the strategic importance of three-dimensional (3D) geoinformation across domains such as planning, the environment, and infrastructure, as an underpinning for government and policy makers (Section 2.2, Table 2.2) and to meet UN Sustainable Development Goals including 7 ("affordable and clean energy"), 11 ("sustainable cities and communities") and 13 ("climate action") (United Nations, 2025).

These policy goals need to be implemented equitably for all citizens, which in turn requires that any 3D data should be created and delivered across an entire nation. This is the role of National Mapping and Cadastral Agencies (NMCAs), who are tasked with "providing consistent, reliable mapping for the nation" (Lawrence, 2004) (Section 2.1). As the research landscape is evolving, with advanced acquisition and modelling techniques, new standards, open tooling, and increasing cross-domain integration, NMCAs are investing in 3D models, tools, and services.

Research on 3D data dates back to the early 1990s (Raper, 1992) and covers approaches to generate the required 3D models (e.g. from point clouds (Xu and Stilla, 2021), from a combination of point clouds and other data such as building footprints (Lakshmanan and Nagarajan, 2025)), to visualise data at scale (Usta et al., 2024; Buyukdemircioglu and Kocaman, 2020), and to understand and model specific user and application needs (Section 2.2). However, to date the vast majority of studies relate to cities. The most recent comprehensive multinational 3D study specifically focussing on NMCAs dates back to 2016 (Stoter et al., 2016), and described the state of 3D in eight countries but did not conduct an in-depth exploration of the understanding of 3D applications and requirements from an NMCA perspective, or on the challenges faced by NMCAs in delivering the required data at national scale.

Building on Stoter et al. (2016), this paper revisits this perspective at a point where many NMCAs are moving from experimentation to early operationalisation. We draw on the results of a EuroSDR[1] 3D Special Interest Group (3D SIG) workshop held in January 2026, using the insights from the workshop to address two key topics:

- RQ1: Building on the NMCA understanding of user needs, does their perspective on key application areas align with that held by researchers and other practitioners?
- RQ2: What are the major blockers faced by NMCAs when rolling out 3D data at national scale, and how have these evolved over time?

Understanding to what extent the NMCA perspective on applications of 3D data[2] aligns with the city-centric literature can enable NMCAs to ensure that their products meet user needs. Identifying which barriers have been resolved, which persist, which have gained new prominence, and where misalignments between research and NMCA practice remain also allows both NMCAs and researchers to focus on key blockers.

The key contribution of the paper is an empirically grounded NMCA perspective on why 3D adoption continues to remain challenging despite technical progress. Understanding the NMCA perspective on 3D topographical data is fundamental to ensuring that the opportunities and services enabled by 3D are able to be delivered equitably to all citizens.

[1] EuroSDR is a not-for-profit organisation linking National Mapping and Cadastral Agencies with Research Institutes, Universities and Companies in Europe for the purpose of applied research in spatial data provision, management and delivery, https://eurosdr.net/, Accessed: 21 March 2026.

[2] EuroSDR's Commissions cover all aspects of data from capture to policy, and the 3D SIG uses a broad definition of 3D data to reflect understanding of the term across the whole gamut.

2. Background

2.1 The Role of National Mapping and Cadastral Agencies

National Mapping Agencies (NMAs) are "National government agencies [..] that are chartered to provide national mapping products and services" (UK Government, 2026). They are responsible for "providing consistent, reliable mapping for the nation" for a "number of core purposes such as planning, property valuation and national defence" (Lawrence, 2004). Noting a slightly broader role, EuroGeographics (2020) add that NMAs exist where the state has determined that "it is in the national interest to mandate a public authority to produce maps in support of a public purpose" but also that part of the role includes determining administrative, democratic, judicial or property boundaries, to aid in planning and development and to help improve delivery of public services. While in some countries judicial property boundaries are handled by a separate authority, these responsibilities are often combined with the NMA to form a National Mapping and Cadastral Agency (NMCA). In some cases - e.g. Great Britain, France, the Netherlands - the NM(C)A is also responsible for defining the national coordinate reference system/geodetic framework.

In contrast to private data providers, the NMCAs must ensure that even the most remote areas are mapped in great detail and are updated on a regular basis (Lawrence, 2004). This is of high strategic value and is vital in emergency situations. A second key differentiation for an NMCA is that they *maintain* a database (Capstick et al., 2007) whereas other 3D providers just capture on a bespoke one-off capture with no requirement to update this data unless further contracted to do so. Thirdly, NMCAs are responsible for "developing an underpinning framework that can join together both public- and private-sector information" (Lawrence, 2004).

2.2 Applications of 3D Data

An early list of 3D applications can be found in a 2002 report from an OEEPE[3] workshop "From 2D to 3D- establishment and maintenance of core 3D geospatial databases" (Nebiker, 2002), with additional reviews in Biljecki et al. (2015), Wong and Ellul (2017) and Kumar et al. (2019). Key applications include energy modelling (Kumar et al., 2019; Biljecki et al., 2015; Katal et al., 2022; Uggla et al., 2023), city planning and urban analysis (Kumar et al., 2019; Biljecki et al., 2015; Wong and Ellul, 2017; Hu and Minner, 2023; Ho et al., 2018) and solar irradiation and shadows (Biljecki et al., 2015; Wong and Ellul, 2017; Šiško et al., 2022; Uggla et al., 2023; Ho et al., 2018). The full list of applications can be found in Tables 2 and 5.

2.3 Barriers to 3D Creation and Adoption

Nebiker (2002) note that "national mapping agencies [..] are experiencing an increasing demand for 3D geodata, but that the focus for NMCAs was very much 2D, with 3D only provided via more precise Digital Terrain Models. In 2007, Capstick et al. (2007) looked specifically at 3D issues within the Ordnance Survey, and in 2013, Stoter et al. (2013) reviewed 3D production in four countries - Great Britain, The Netherlands, France and Switzerland and one region (Catalonia). The review highlights early exploration/use of CityGML as a standard for 3D, and two contrasting approaches to 3D data generation - "3D first" - where 2D products are derived from a 3D source and "2D First", extending data into 3D. Building on this, (Stoter et al., 2014) reports the work of ten NMCAs noting a focus on visualisation, that all respondents had some form of Digital Surface Model, with five of the ten having some form of 3D building. A 2016 update from seven NMCAs (Stoter et al., 2016) notes that some participant NMCAs are still at an initial phase, experimenting with 3D data, while others have moved to production at national scale. Finally Ho et al. (2018) take a value-centric perspective to 3D, considering economic perspectives but also noting that 3D valuation goes beyond finance due to its role in enabling public services and policies.

A number of key barriers and challenges are consistently mentioned throughout the sixteen-year timespan covered by literature (2002 to 2018), including:

- Challenges of multiple representation and aligning 2D and 3D data (Nebiker, 2002; Capstick et al., 2007; Stoter et al., 2013, 2014)
- Standards - mentioned as a gap by Nebiker (2002), with GML as an 'emerging' option mentioned by (Capstick et al., 2007), with Stoter et al. (2013) noting that CityGML has become more established and Stoter et al. (2014) noting that the standard has evolved to the point that there are specific needs to model detailed features such as canopies
- Automation - starting with a general need for automation in Nebiker (2002); Capstick et al. (2007) but moving to specifically mention national scale rollout in Stoter et al. (2013, 2016)
- Tooling/software/processes - the need for 2D centric tools to be adapted to 3D in Capstick et al. (2007) to challenges of large data volumes (Stoter et al., 2013), and potential for co-production with third parties (Ho et al., 2018)
- Economic feasibility - is 3D economically viable, is there value (Capstick et al., 2007; Stoter et al., 2016)? A particular challenge relates to the fact that 3D does not improve existing processes (Stoter et al., 2013) and the difficulty in articulating value that is achieved further downstream as e.g. secure land tenure afforded by 3D cadastral systems is not linked back to high-quality 3D data (Ho et al., 2018).

Additional challenges include integration with third party data (Nebiker, 2002; Stoter et al., 2014, 2016); understanding user requirements (Capstick et al., 2007; Stoter et al., 2013; Ho et al., 2018) training within the NMCA; end users access to training and access to 3D software (Stoter et al., 2013, 2016); update-related challenges emerge (Stoter et al., 2013, 2016), as production of the first national 3D datasets emerges. One-off mentions are given to: 3D generalisation, 3D topology and indoor/outdoor integration (Nebiker, 2002); managing and documenting uncertainty, data fusion (LiDAR, photogrammetry), integration of above/below surface data (Stoter et al., 2014).

3. Method

EuroSDR's 3D Specialist Interest Group (3D SIG) convened a workshop in London in January 2026, entitled: "The way forward for 3D mapping at national and regional mapping agencies", posing questions including those shown in Table 1[4]. The workshop aimed to identify areas for further research

[3] OEEPE - European Organisation for Experimental Photogrammetric Research - is the predecessor of EuroSDR

[4] The workshop builds on a previous initiative in Paris in 2025. Material from both events can be found here: `https://eurosdr.net/workshops/past`, Accessed 26th March 2026

and technical/non-technical priorities, establishing a research agenda for co-development with NMCAs across the clusters of acquisition, modelling, maintenance and use of 3D data.

The event targeted a broad range of NMCAs with different levels of 3D maturity and interest, from those for whom 3D products are well established, across those for whom 3D was a small, niche, product in the NMCA to those starting with 3D and wanting to learn more about potential approaches and benefits. The workshop was advertised to 69 members of the core EuroSDR mailing list which reaches NMCAs in 22 countries and nine associate members, and on social media.

Facilitated breakout sessions were held to address the questions in Table 1, where participants were asked to write ideas and comments on Post-it notes and discuss the different viewpoints as they emerged.

Our overall approach is deductive thematic analysis with a priori themes (Kuckartz and Rädiker, 2023) informed by author expertise and overall objectives of the workshop. These themes were expressed as the categories/instructions within each breakout session. For the first question (goals and user needs), participants were asked to categorise identified application areas under headings related to the main user group for the specific application - public sector (local or national), private sector, academia, NMCA, third sector, other. For the second question (technical and non-technical barriers) participants were asked to split their Post-its across challenges that are easier to achieve versus those that may take longer/require more effort and hence are more difficult to achieve.

3.1 Processing the Data

Captured Post-it notes were digitalised and an adapted thematic analysis process was conducted, building on the process outlined in Braun and Clarke (2021) and Kuckartz and Rädiker (2023):

- Assign text to categories: carried out by participants during the workshop
- Data clean-up and initial review: reading through all the Post-it notes and removing irrelevant data
- Review Category Content: our use of Post-its means that the text is already split into excerpts/codes. Where Post-it notes contained information relating to multiple concepts, the text was split into smaller components.
- Identify sub categories: takes advantage of researchers' expertise to group codes that seem to share a core idea or concept in relation to the research topic or question - initial codes are grouped into higher level categories. A multi-stage approach is taken here, where initial sub categories are reviewed and improved iteratively.
- Summarising results: counting the number of entries related to each application area and exploring the understanding of 3D use cases across the different participant nations. For the challenges, evidence was summarised separately for technical and non-technical themes.

3.2 Addressing the Research Questions

To compare the applications that are the focus of NMCAs to those identified in literature (RQ1) three lists were generated: applications identified by NMCAs and in literature, applications only identified in literature, applications only identified by NMCAs. The challenges identified in Section 2.3 were compared to those identified from the workshop, on a case-by-case basis (RQ2). For each pre-existing challenge, the original mention (year) was noted, along with a description of if/how progress has been made and the challenge has evolved over time.

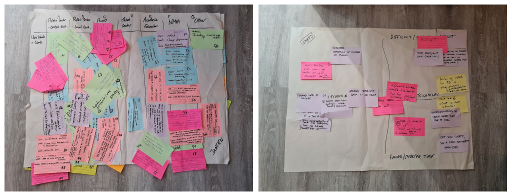

Figure 1. Sample Workshop Outputs - Applications ordered by User Type / Sector, and Technical/Non-Technical Challenges

4. Results

4.1 Processing the Data

The workshop brought together 43 3D experts from NMCAs in twelve countries. Participants represented a wide range of perspectives, technical backgrounds, and levels of 3D "maturity" within the NMCAs. Participant counts are as follows: Catalonia (2); Denmark(1); Estonia(2); Finland (2); France (5); Germany (2); Netherlands (1); Norway (1); Slovenia (7); Spain (1); Sweden (4); Switzerland (1); United Kingdom (14). Spain and Catalonia are listed separately as representatives from both the national and the regional mapping agency were present. One additional participant - a representative of a software vendor with reach across Europe - provided a Europe-wide perspective, included in the overall counts but not in the NMCA results.

Figure 1 shows a sample of the raw data captured during the workshop, with Table 1 showing the number of Post-its per question, and the number of 'codes' following post-processing.

Breakout	Post-Its	Codes
What goals and user needs should NMCA 3D data meet?	232	275
What gaps still exist - technical or non-technical - that are (partly) preventing NMCAs from meeting these goals?	99	99

Table 1. Post-its and split "codes" for each question

4.1.1 Application Domains Table 2 shows the applications identified during the workshop, split by country[5]. Those countries with a higher number of representatives in the room contributed a higher number of applications to the discussion. Urban and spatial planning, emergency response and flooding are the most popular across countries. A specific focus area emerges - 'forestry' which was mentioned by countries where forests are of national importance either as a natural resource and/or due to fire hazards - i.e. Estonia, Finland, France, Slovenia, Spain, Sweden - but not by the UK, Germany, The Netherlands or Switzerland.

[5] A total of 39 of the 275 data points made reference to data quality or a generic requirement rather than an application, with 8 additional Post-its referring to algorithms and technical issues and 16 containing data that was not relevant. These were removed from analysis.

Country	Applications
Catalonia	Accessibility, Emergency Response/Disaster/Risk, Flooding, Heat Loss, Heat Islands, Renewable Energy, Telecommunications, Tourism
Denmark	Flooding
Estonia	Cadastre, Flight Obstacle Detection, Flight Planning - air traffic, drones, Flooding, Forestry, Renewable Energy, Research, Urban and Spatial Planning/Building Permits, Urban Form and Change Detection
Finland	Defence/Military, Flooding, Forestry, Transportation, Urban and Spatial Planning/Building Permits
France	Agriculture, Climate Change, Construction, Defence/Military, Flooding, Forestry, Insurance, Noise, Other, Real Estate, Renewable Energy, Telecommunications, Transportation, Urban and Spatial Planning/Building Permits
Netherlands	Emergency Response/Disaster/Risk, Noise, Renewable Energy, Urban and Spatial Planning/Building Permits
Norway	Autonomous Vehicles, Emergency Response/Disaster/Risk, Other, Real Estate, Research, Urban and Spatial Planning/Building Permits
Poland	Agriculture, Heat Loss, Heat Islands, Lighting/Shadow, Noise
Slovenia	Agriculture, Asset/Facility Management, Cadastre, Climate Change, Construction, Emergency Response/Disaster/Risk, Flooding, Forestry, Green space, Infrastructure, Insurance, Logistics, Navigation - Indoor and/or Outdoor, Other, Real Estate, Renewable Energy, Research, Tourism, Urban and Spatial Planning/Building Permits, Urban Form and Change Detection, Utilities/underground, Water management
Spain	Climate Change, Construction, Forestry, Tourism
Sweden	Climate Change, Defence/Military, Emergency Response/Disaster/Risk, Flight Obstacle Detection, Flight Planning - air traffic, drones, Flooding, Forestry, Infrastructure, Insurance, Noise, Other, Real Estate, Renewable Energy, Telecommunications, Urban and Spatial Planning/Building Permits
Switzerland	Flight Obstacle Detection, Flight Planning - air traffic, drones, Other, Utilities/underground
UK	Agriculture, Air Quality, Asset/Facility Management, Autonomous Vehicles, Defence/Military, Emergency Response/Disaster/Risk, Flight Obstacle Detection, Flight Planning - air traffic, drones, Flooding, Gaming, Heat Loss, Heat Islands, Infrastructure, Insurance, National Security, Navigation - Indoor and/or Outdoor, Noise, Real Estate, Research, Telecommunications, Transportation, Urban and Spatial Planning/Building Permits, Urban Form and Change Detection

Table 2. Identified 3D Applications, by NMCA

4.1.2 Barriers to 3D Creation and Adoption Non-technical suggestions include:

- **Collaboration and Knowledge Exchange**: developing better understanding between government and private sector; fostering exchange with academia and end users
- **Funding and Value Propositions**: quantifying cost benefit for specific cases such as flooding; establishing a business case for 3D, with indirect challenges around finding budget for more frequent data updates. (16 Post-its, general funding/budget issues are 'relatively difficult' or 'difficult'; the variety of value propositions is 'difficult')
- **Role of the NMCA**: clarifying the role of the NMCA with respect to other players in this area - what should the NMCA deliver, what should others - specifically municipalities and/or the private sector - deliver? (3 Post-its, all identified as medium or relatively easy difficulty)
- **Understanding Users/Developing Use Cases**: this is circular - users do not have good knowledge of 3D as little 3D data is available, but because of this it is difficult to develop use cases that make the case for 3D. 'One size does not fit all' but it is a challenge for NMCAs to deliver bespoke products. Understanding when 2D is sufficient/when 3D is needed is key (11 Post-its, 2 rated this 'Relatively difficult', all others as middle, relatively easy or easy)
- **Additional comments**: the need for training; improving 3D data usability; understanding the role of specifications

Challenges identified from a technical perspective include:

- **2D/3D interoperability**: the fusion of multiple 3D data sources, e.g. cadastral and 3D topographic data; transferring semantics between 2D and 3D datasets; the need for the 3D data to act as an 'anchor' for other datasets, due to the NMCA role as a reference for third party data
- **The possibility of a '3D first' approach**: where the default data products are 3D and 2D is derived from this
- **Algorithmic complexity**: of specific tasks such as appending semantics to 3D mesh data, and balancing the cost of additional geometry/topology complexity due to 3D
- **Automated update and change detection**: the need to keep data up to date and emerging needs for more frequent data update cycles, with consequent additional technical challenges and cost, as well as absorbing updates from external sources such as sensors and building permits
- **Feature extraction**: e.g. number of floors for cadastral mapping, identifying bridges, accurate roof geometry
- **Skills gaps** as 3D requires enhanced skills but these are not necessarily available within NMCAs
- **Standardisation**: selecting/agreeing standards, harmonising local and national models, converting formats
- **Technical infrastructure**: the need for larger storage capacity, especially for LiDAR/obliques; deciding whether to adapt current workflows or start from scratch; use of off-the-shelf versus bespoke software

Granularity of the Post-its varied - e.g. in technical infrastructure we have "storage of data" and "Oblique + LiDAR require many times more processing and storage". Technical and non-technical categories overlap - use cases are mentioned both in terms of the need and of the technology. Change detection, identifying appropriate specifications, understanding local/national approaches, connecting 3D topography and cadastral systems were placed in the middle of the chart - i.e. technical/non-technical, middle level difficulty. Overall, the more active discussions focussed on non-technical issues. Making the case for funding for 3D data capture and update is key.

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Application	#mentions	#countries	Review Sources
Climate (e.g. heat islands, microclimates, renewable energy, solar power, shadows, climate change, flooding)	34	11	(Kumar et al., 2019; Katal et al., 2022; Nebiker, 2002; Biljecki et al., 2015; Wong and Ellul, 2017; Šiško et al., 2022; Uggla et al., 2023; Ho et al., 2018)
Urban Planning (e.g. urban form, change detection, green area design)	32	9	(Šiško et al., 2022; Kumar et al., 2019; Biljecki et al., 2015; Wong and Ellul, 2017; Hu and Minner, 2023; Ho et al., 2018; Nebiker, 2002; Biljecki et al., 2015)
Infrastructure and Transport (e.g. telecommunications, visibility analysis, radio wave propagation, public transport, automated driving)	24	7	(Kumar et al., 2019; Ho et al., 2018; Nebiker, 2002; Biljecki et al., 2015)
Emergency Response (e.g. disaster management, risk assessment)	23	7	(Biljecki et al., 2015; Wong and Ellul, 2017; Šiško et al., 2022; Ho et al., 2018; Nebiker, 2002)
Real Estate	13	5	(Kumar et al., 2019; Ho et al., 2018)
Forestry (e.g. urban forests)	10	6	(Biljecki et al., 2015; Ho et al., 2018; Münzinger et al., 2022)
Human Comfort (e.g. noise)	6	6	(Kumar et al., 2019; Biljecki et al., 2015; Šiško et al., 2022; Uggla et al., 2023; Ho et al., 2018; Nebiker, 2002)
Insurance	6	3	(Wong and Ellul, 2017)
Agriculture (e.g.precision farming)	1	1	(Kumar et al., 2019)
Cadastral Systems (e.g. underground land administration, subsurface management)	1	1	(Kumar et al., 2019; Biljecki et al., 2015; Wong and Ellul, 2017; Ho et al., 2018; Saeidian et al., 2023)
Gaming	1	1	(Wong and Ellul, 2017)
Navigation (e.g. outdoor, visualisation for navigation)	1	1	(Nebiker, 2002; Biljecki et al., 2015)
Tourism	1	1	(Šiško et al., 2022)

Table 3. Applications Mentioned by Both: Comparing Review and NMCA-Identified 3D Application Categories, with additional specific examples where these were mentioned.

Table 4 lists applications that were mentioned by NMCAs but not the literature. Flight planning is a core data capture method within NMCAs but far less used elsewhere (licensing/flight restrictions prevent many drone operators from the extended flights where 3D data might be relevant for planning). The emergence of defence and security further highlights the importance of 'national' coverage of data and may also reflect that NMCAs may have additional security approvals and engage in 3D-related work that is not shared with the public.

Application	#mentions	#countries
Flight planning (air plane or drone)	1	1
Defence/Military	6	5
National Security	1	1

Table 4. Applications Mentioned by NMCA only

Table 5 lists the applications that were not mentioned by NMCA but were identified from literature. Many of these applications have at least some relationship to those listed in Table 4 - e.g. heat loss/energy modelling topics are often considered alongside renewable energy and are part of wider work on climate change; cultural heritage and history are related to tourism; utility lines are commonly considered when making flight plans for drones; wind modelling underpins air pollution modelling.

Application	Review Sources
Infrastructure/ Safety (e.g. traffic design and management, utility lines, CFD/wind modelling)	(Šiško et al., 2022; Nebiker, 2002; Kumar et al., 2019; Ho et al., 2018; Biljecki et al., 2015; Uggla et al., 2023)
Humanitarian Crises	(Kumar et al., 2019)
Health	(Kumar et al., 2019)
Heritage (e.g. cultural heritage, history, archaeology)	(Wong and Ellul, 2017; Hu and Minner, 2023; Šiško et al., 2022; Kumar et al., 2019; Biljecki et al., 2015)
Smart Cities	(Kumar et al., 2019)
Environmental Processes (erosion modelling, hydrology and geo-hazards, geology)	(Nebiker, 2002; Kumar et al., 2019; Biljecki et al., 2015)
Human Comfort (e.g. heat loss, energy modelling, air quality	(Kumar et al., 2019; Biljecki et al., 2015; Katal et al., 2022; Uggla et al., 2023; Kumar et al., 2019; Wong and Ellul, 2017; Nebiker, 2002)

Table 5. Applications Mentioned by Review Only: Comparing Review and NMCA-Identified 3D Application Categories, with additional specific examples where these were mentioned.

Additional applications mentioned by NMCA participants ('indoor navigation'), identified by the review ('facility management' (Biljecki et al., 2015; Wong and Ellul, 2017) and 'floorspace estimations' (Biljecki et al., 2015)) and by both ('cadastral applications') were not considered as currently NMCA 3D activity focusses purely on building exteriors and does not as yet include consideration of in-building data.

4.2.2 Barriers to 3D Creation and Adoption Comparing the results to previous work in Section 2.3, it can be seen that a number of issues remain constant: funding and value propositions; the need for training and skills development; 2D/3D alignment and interoperability challenges; automated updates and change detection; standardisation (despite the evolution from no standards at all in Nebiker (2002) to the strong use of CityGML terminology - in particular Levels of Detail - in Stoter et al. (2016); technical infrastructure challenges, perhaps reflecting that even as we overcome data related challenges more and more detailed data is generated by newer sensors. Given that Stoter et al. (2013) noted that some NMCAs had already started to explore a 3D-first approach, it is interesting to note that developing a better understanding, the feasibility of a 2D first or 3D first or an integrated approach is still listed.

Understanding users/use cases (and "why 3D") has emerged as a key challenge, which is perhaps surprising given the long list in Table 5. It seems that there has been little change in this regard over the years - there is a need to develop products that meet a wide range of use cases, and also a need for users to understand what can be done with 3D data.

In comparison to previous literature, perhaps the only 'new' challenge identified in the above list is the need to better define the role of an NMCA in producing 3D data, in particular given competition from private sector companies now able to produce 3D models on demand. This is not a recent challenge - however it could be suggested that it has been brought to the fore in the workshop due to increasing budgetary pressures and changes to expected outputs from NMCAs.

5. Discussion

This paper explored NMCA understanding of user needs for 3D data, and identified that as a group NMCAs do possess a good understanding of potential application areas for their 3D data, and these broadly align with those listed in literature. Defence/Military and National Security applications stand out as areas where there is NMCA focus but that are - to our understanding - not clearly articulated elsewhere.

We also identified key major blockers faced by NMCAs when rolling out 3D data at national scale. From a technical perspective, persistent challenges relate to 2D/3D data fusion, and to the incorporation and interoperability of multiple data sources, along with automated update and standardisation. Non-technical challenges relate to understanding use cases and to funding and value propositions. An emerging theme is the role of NMCAs with respect to other providers of similar data.

5.1 Use Cases and Applications

Despite the diverse backgrounds, expertise, national drivers and context of the participants, three key areas - climate, urban planning/change detection and infrastructure emerge as dominant areas to explore in a collaborative fashion. However, Tables 3, 4 and 5 also demonstrate that the level of granularity with which an application is described is variable - in most cases application areas are listed rather than specific detailed applications. For example, "Smart Cities" could encompass many other applications on the list, as could "Health", and "Defence/Military" and "Real Estate". A lack of application-specific detail can result in uncertainty for data model design and implementation.

More broadly, the heterogeneity of applications reflects Ho et al. (2018), who note that the diversity of ways that 3D can benefit the public is a challenge as the sheer number of applications makes it difficult to consolidate such a broad user base. This fragmentation of applications is reflected in the number of applications identified in Tables 3 and 5. In short, there is no one "killer app" for 3D geospatial data.

It can also be noted that Digital Twins did not emerge as a separate theme. This may reflect the fact that Twins and 3D data are often conflated/seen as the same thing in a geospatial context. Emerging Twin applications may develop into core applications for 3D, particularly when National Twins - which will require consistent, high-quality data across an entire nation are considered. However, it should also be considered that the main focus of the workshop was 3D rather than Twins, and while there are similarities and overlaps the two are not identical.

To date, the main focus of 3D activity within NMCAs is modelling the exterior features of buildings and the external environment, and there is less consideration of how interior models can be incorporated. This may change over time, in particular as GeoBIM (the combination of 3D geospatial data and Building Information Models) applications such as digital planning permit processes (e.g. Noardo et al. (2020)), 3D cadastral modelling (e.g. Guler et al. (2022)) and asset/facilities management (e.g. Congiu et al. (2024)) become more prevalent, increasing the availability of detailed 3D models of buildings.

Both Digital Twins and applications combining indoor and outdoor modelling are instances of a wider requirement for NMCAs to develop new partnerships and commercial models, especially as many of the benefits of 3D data will need to be realised across government and in industry, but are very difficult for NMCAs to monetise.

5.2 Evolution of Barriers over Time

Given the relative subjectivity of the methods used both by this and previous studies - where results depend on the knowledge of the 3D experts - it is perhaps not accurate to conclude that if a barrier was only mentioned in 2002 it no longer exists. Rather the changes in barriers over time could reflect a different focus within the NMCA community and an evolving understanding of their role as creators of 3D geospatial data, along with progress in technology and changes in the wider geospatial context. For example, 3D topology may no longer be a key issue as within the wider community topological data structures are now replaced by "spaghetti" models with no inherent topology (given the increasing dominance of spatial databases). In contrast, data fusion issues, first mentioned in Stoter et al. (2014) emerge as a consistent theme - as one problem is solved, newer data capture approaches - combined sensors for oblique and nadir, national scale LiDAR, mobile mapping/drones - add further challenges.

Similarly, standards - first mentioned in 2002 (Nebiker, 2002) are still considered a challenge despite the emergence of CityGML (and in particular the use of its Levels of Detail as descriptors that are well understood by the entire community from 2014 onwards). The aspects of standardisation specified as 'relatively difficult' relate to harmonising local and national specifications, converting between CityGML and CityJSON, as well as the concept that detail should only be added where needed for specific applications. The lack of understanding of 3D data and of available tools are also mentioned, reinforcing the need for training both within the NMCA and for end users.

5.3 Further Considerations for NMCAs

As noted by Mark Griffith, CEO of Ordnance Survey "producing high-quality authoritative data builds trust which is essential for sustainability reporting and confident decision making by businesses and governments, helping to avoid reputational risks from inaccurate data" (Chartered Institution of Civil Engineering Surveyors (CICES), 2026). Providing high-quality, national coverage data and ensuring regular update is core to an NMCA role, and is a key differentiator from other providers (Section 2.1). Resulting 'national scale' challenges have been consistently mentioned since 2013, and may be a priority focus. Indeed, creating trust and understanding and describing data quality, quality differentiators and fitness-for-purpose in a way that is clear to users becomes increasingly important when open third party datasets such as the 2.7 billion building "GlobalBuildingAtlas" from TU Munich emerge (Zhu et al., 2025).

The review by (Lei et al., 2023) highlights that bigger cities have the funding to develop their own 3D models independently of national activity. However, many of the applications listed in Table 2 are in fact national in scope, and moving forwards it will be important to ensure that these services can be delivered consistently to any citizen no matter their location. A related challenge is understanding if/how third party data (e.g. if a city develops its own 3D model) can be incorporated into national scale 3D while maintaining consistency of data.

As 3D moves from research/small experiments into production, it will become increasingly important to make a strong case for justifying investment. As well as understanding users, partnerships and technical issues such as multi-source data integration, to start to address this challenge the broader role of an NMCA - and in particular the remit to create consistent data for an entire nation to ensure equitable services for all citizens - is very relevant, as is the remit to update data on an increasingly frequent basis to meet evolving demand.

5.4 Limitations

To give context to the above results, it is important to note that in both the recent and previous workshops evidence was gathered from NMCA colleagues with expertise in 3D, but the number of participant countries is relatively small. There is also a bias as it is likely that the NMCAs who are further along the road to full 3D data production are able to provide more input into those discussions than those just starting out. The number of UK-based participants will also bias the overall result. The language of the workshop was English, and while participants are generally very fluent there was a specific issue noted around the term "third sector" (not-for-profit organisations).

In terms of processing the data, it could be argued that full thematic analysis (including coding (Braun and Clarke, 2021)) is best practice for qualitative data. However, given that we asked our participants to place Post-it notes into pre-defined categories, deductive category formation, where a-priori high level categories are developed in advance of the event based on pre-existing theory and knowledge of the subject (Kuckartz and Rädiker, 2023) was selected. This is particularly relevant as we made use of Post-it notes rather than having a one-to-one conversation with a single individual which means that the initial text consists of pre-categorised short phrases, rather than long sentences, leaving far less scope for coding uncertainty.

It should, however, be noted that any thematic analysis is subjective and re-interpretation of the data may result in slightly different applications and challenges, although it is not likely that significant differences would be observed. All data has been retained for further analysis if required.

5.5 Further Work

The findings in this paper serve as a foundation for future activities in the EuroSDR 3D SIG. As well as addressing technical challenges, research in this area should address non-technical issues such as user training, understanding the role of NMCAs and how best to work with, and integrate data from, other data providers. A key issue - in particular given the diverse range of potential applications using 3D geospatial data - is how to move beyond use cases and demonstrators and better make the case for investment in 3D data production both within an NMCA and to policy makers/funders. More generally, further work will also include prioritising the barriers with 3D SIG members, and potentially forming working groups to address them, taking advantage of the Europe-wide research/NMCA collaboration enabled by EuroSDR.

6. Conclusion

This paper explored an NMCA perspective on the current generation of 3D geospatial data and how it is expected to evolve in the future, noting specific challenges emerging from a remit to generate such data at national scale. Outreach for the event specifically targeted NMCAs meaning that the results represent a national data-producer-centric viewpoint, with complementary insights to those from existing more user-centric research. Our findings provide NMCAs with an extended list of 3D-related applications that will help to make the case for further investment in 3D data production. Understanding challenges to address and how these have evolved over time can also help to prioritise areas of research, development and investment.

Our results also highlight the benefit of a collaborative approach such as that facilitated by the EuroSDR 3D SIG, avoiding duplication and sharing insights and learning as to what works and what does not. The results can assist other NMCAs along their 3D journey, enabling the exploration of aligned approaches and standards that may result in economies of scale through shared software development and shared data capture approaches and workflows.

To quote one of our participants "it is not really a question of whether to 3D or not 3D, but more of how much to 3D."

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