Exploring 3D Cadastres in India: Evaluating the Potential for Land Planning, Development and Management in Delhi

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Key words: 3D Cadastre, Delhi, Land, Planning, Development, Management

SUMMARY

Urbanization and the trend towards complex infrastructure development has challenged the traditional two dimensional cadastral representations used in conventional land administration. Three dimensional representations, using three dimensional geometric primitives, are argued to serve as the future basis upon which to define rights, restrictions and responsibilities more accurately in these environments. The challenge manifests itself in Delhi, the metro and capital city of India, where horizontal expansion via new settlements in peri-urban areas, and vertical expansion by densification of city infrastructure are witnessed. The need to manage this increasingly 3D infrastructure environment presents a great challenge for both the Delhi Development Authority, the primary agency responsible for land planning and development, and the Municipal Corporation in Delhi, responsible for the maintenance of a large part of the city. This paper explores the current status of three dimensional representations in land related planning, development and management works in Delhi. To achieve this purpose, the outcomes of several research activities are consolidated. Underpinning the work was an analytical framework, informed by international works, enabling assessment of the existing form, function, and implementation of three dimensional cadastre. A questionnaire of employees from within the focus organizations was conducted with random sampling used to identify participants. The questionnaire enabled participants to outline current practices and understandings regarding three dimensional representations, potential benefits, organizational capacity and available technologies. In parallel, qualitative analysis was performed in the form of a literature review on the potential application of conceptual models related to land administration (LADM), data models about city infrastructure representation (CityGML) and building level information (BIM) etc. in context of Delhi as a case study. Based on the results, it is concluded that current practices related to 3D representation are immature and not adequate for capturing the future vertical growth of Delhi. This could lead to legal and physical boundary inconsistencies, irregularities, and dispute cases. However, adopting the international standard approaches, the agencies have the potential to enhance and support processes in the respective organizations. To realize this potential, internal and external factors related to policy, institutional setups, technical and financial arrangements need to be calibrated. It is recommended to initially focus on raising awareness for the widespread adoption of 3D representations in such organizations in Delhi.

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1. INTRODUCTION

Urbanization is a global phenomenon that raises the density of infrastructure to accommodate growing populations in limited spaces. Increased urban density provides greater economic opportunity to adopt development of vertical structures (urban-hub, 2018; Kodmany, 2012; Antoniucci, et. al., 2017).

Vertical development raises an economic and social need to define and demarcate legal and physical rights, restrictions and responsibilities (RRRs) for individual and commonly owned units (Paasch, 2016). Clearly demarcated RRRs assist in removing social conflict and can boost economic development through easier land dealings (World Bank, n.d.). Traditionally, land administration has managed cadastral requirements with two dimensional maps (Ho et al, 2015; Rajabifard, 2015), however, for increasingly complex infrastructure, 2D representations are challenged to represent depths or heights in a graphic manner (Oosterom et al., 2011; Ying et al., 2012; Kitsakis et al., 2016). It is increasingly argued that 3D representations should be adopted during all the phases of urban development (van Oosterom, 2013). Such representation is required to involve the communities residing in a city, in addition to land planners, developers, managers and administrators. 3D representations can support a more participatory approach for decision making which can help in the sustainable development of cities (Hassan et al., 2011; Lane, 2015).

The combination of above mentioned challenges and opportunities manifest themselves in Delhi, the metro and capital city of India – although, until now very little has been researched on developments relating to 3D representations and cadastre within the city. Two agencies are seen as key to these developments. The Delhi Development Authority (DDA) is primarily responsible for land planning and development, while the Municipal Corporation in Delhi (MCD), in its trifurcate form of Southwest, North and East Delhi municipal corporations, is responsible for the maintenance of a large part of the city (DDA, 2018; MCD, 2018).

Unpacking the strategic and operational developments, relating to 3D cadastre, is the focus of this paper. The aim is to explore the current status of 3D awareness, representations and cadastre in land-related planning, development and management works of DDA and MCD, with view to identifying existing limitations and future opportunities for enhanced utilization of 3D data. To be specific, it will try to find the answer the following questions: i) How do the agencies currently use 3D representation and data capture? ii) How do the agencies understand 3D concepts in relation to their work? and iii) What are the areas having potential for the two agencies with relation to 3D?

2. BACKGROUND

Like many urban centres in developing economies, Delhi has grown rapidly over the last few decades with much of its outer extent being converted from agricultural land use. Infrastructure density has increased and different landuse types compete for space (Jain et al., 2016a; Jain et al., 2016b). Competition is not only restricted to horizontal space, but, also results in overlapping claims in the vertical dimension. In addition to four- story apartments in regular and unauthorized colonies, Delhi has areas with high-rise residential apartments, for more than a million residents in Patparganj, Mayur Vihar, Rohini and subcity of Dwarka. Different types of utility networks, owned or managed by various agencies have occupied the space under, on and above the surface of the city. Ghawana et al., 2013 described the situation of 3D cadastre with detailed case studies of utility networks on Dhaula Kuan traffic point.

Delhi, driven by the smart cities mission of India (smartcities-India, 2017), is redeveloping and seeking to move towards infrastructure modernization. The redevelopment is leading to densification of infrastructure and generating 3D complex structures for different purposes. With ongoing redevelopment plans such as in East-Kidwai Nagar and Shajahanabad, while continuing the trend of establishing new metro lines and flyovers, 3D infrastructure development will continue to be a dominant issue in city governance. To date representations of the spatial units, infrastructural plans and blueprints are generally understood to be in 2D format in digital representations, with very few exceptions.

2.1 Delhi Development Authority and Municipal Corporation of Delhi

As mentioned, DDA and MCD have a major role in land development planning and its management inside the jurisdiction. DDA makes zonal plans and performs development processes including boundary demarcation, utility network creation and other infrastructure establishment activities for new settlements or colonies. DDA is occasionally involved in redevelopment of sites under its control. It is also involved in allotment, registration (leasehold/freehold) and stamp duty collection processes. DDA collects ground rent for properties which are on leasehold after allotment. The functional relationship between the two agencies is shown in Figure 1. DDA and MCD are involved with mutation processes for properties in Delhi, with MCD doing the process in case of de-notified urban areas by DDA. De-notifying an area by DDA allows MCD to take control of building activities and applying provisions of the Municipal Corporation Act. The responsibility of maintaining the areas lies with MCD. It involves interventions from MCD to implement the development plans in its jurisdiction. This includes surveying measurements, encroachment checks, construction and maintenance of certain roads, and other infrastructure management. Property tax is also collected by MCD on an annual basis in de-notified areas. Thus, both agencies actively handle spatial units of land and built properties, and the information relating to those. With 3D construction of complex infrastructure, the necessity of adopting 3D cadasters for both agencies is more and more apparent: performing the increasingly complex functions and clearly defining the associated RRRs vis-à-vis individual properties demands such an approach.

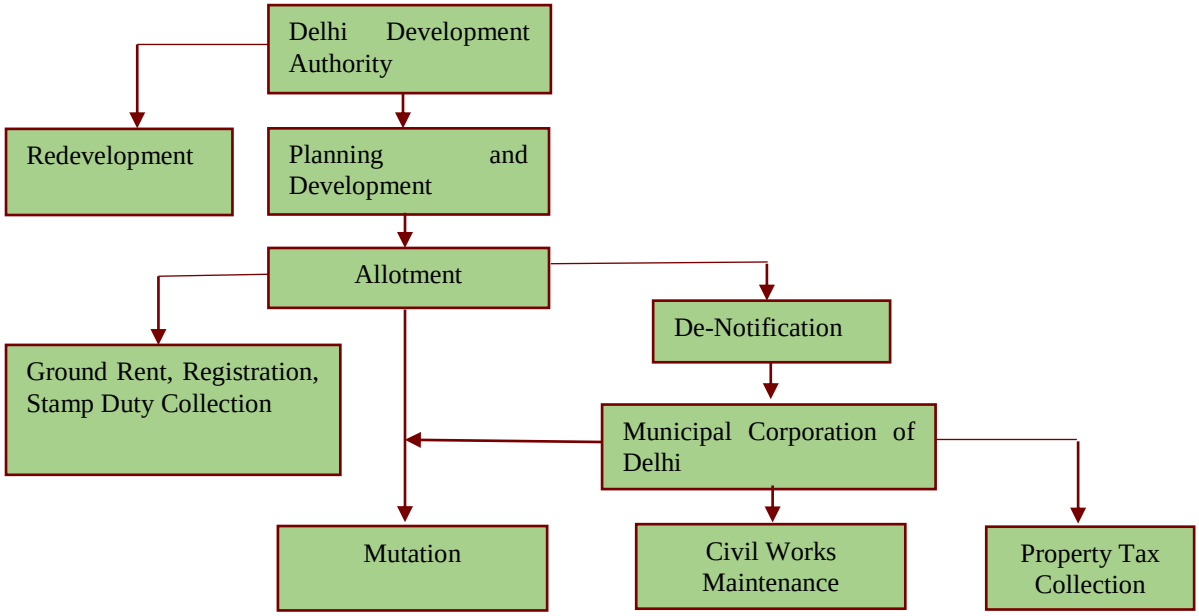

Figure 1. Functional Relationship between Delhi Development Authority and Municipal Corporation

2.2 International Standards of 3D Representation Vis-à-vis Growth in Delhi

In addition to understanding the structure and role of DDA and MCD, it is useful to provide background on 3D international standards that can inform an analysis on the status of Delhi's 3D data arrangements – and later adoption. Such adoption could help to accommodate, more efficiently, the demands of legal, physical, topological and geometrical natures inherent to complex infrastructure. The standards include pre-defined components, rules and functionalities with enough flexibility or scope for adaptation in these standards. A potential benefit of maintaining compatibility with international standards is that any relevant development in these standards can be utilized by the local authorities as per the requirements of Delhi infrastructure.

In this context the Land Administration Domain Model (LADM, ISO 19152) is mentionable as a conceptual generic model with information components related to land administration including elements above and below the surface of the earth (LADM ISO19152, 2012). In the case of Delhi, 3D complex infrastructure development, following LADM as the base model, will provide a flexible foundation of a system capable of accommodating legal and administrative aspects, along with spatial aspects to clearly help in demarcating rights and restrictions of 3D units of exclusive and common ownership.

Going further, transforming the relevant parts of the LADM conceptual model to a data standard, DDA and MCD could consider the relevance of CityGML (CityGML, 2017)., an open standard data model and exchange format, allowing city level infrastructure and landscapes to be digitally stored as 3D representations, as shown in Figure 5. With this model, planners, designers and developers can describe the common features of Delhi city such as buildings, roads, and so on, along with their relationships in different level of details as per their requirement. CityGML can also store the specific 3D relationship between objects such

as underground Delhi metro stations connecting to its surface level vehicle parking. Narrowing down from city level infrastructure standards and exchange formats to information or modelling standards for individual complex buildings, DDA and MCD could include Building Information Management (BIM) models facilitating multi-disciplinary coordination and integrate 3D design, analysis, cost estimating and construction scheduling. These models can support facilities management and building operations (McArthur, 2015) (New Zealand BIM Handbook, 2014) (Dehbi et al., 2017).

Finally, 2D CAD is the most common format for designing and presenting the layout plans in a digital way, however, BIM software allow digital representation of physical and functional characteristics of a structure in 3D while capturing different types of data. Simulations could be performed by the DDA and MCD for the decision making considering client requests, development and municipal regulations, while linking project planning to construction planning. This would also enable visualization during construction and digital fabrication (Autodesk, n.d.).

3. METHODOLOGY

This study is about exploring the need, benefits, challenges and current practice of 3D representations and cadastre within the functional brief of two key land governance agencies in Delhi. A case study approach is applied: it supports the broad inquiry on the specific organizations, whilst also enabling targeted analysis of specific phenomena and issues within those organizations. For this study, East Delhi Municipal Corporation (EDMC), was selected to represent MCD activities due to ease of access for data collection. Primary data was collected about conceptual understandings, technical-financial capacities, data models or software, and current practices, amongst others - related to 3D representation and cadastre in DDA and East Delhi Municipal Corporation (EDMC) from the employees of DDA and MCD. This occurred through the delivery of questionnaire based interviews. An analytical framework, informed by international works, was used to organize the data collection and analysis, enabling assessment of the form, function, and implementation of 3D representations and cadaster.

The collected primary data was summarized to enable quantitative analysis. Further, the results were then considered in the context of the aim for future recommendations. The methodological framework given in Figure 2 describes the methodology in a graphic form.

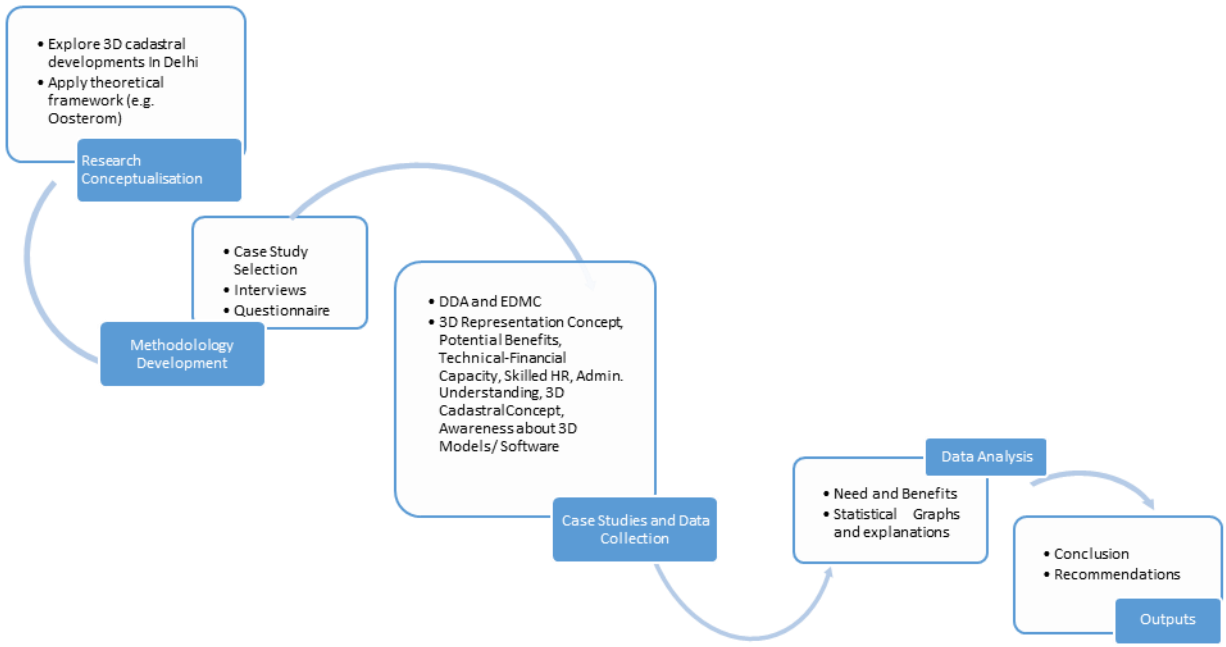

Figure 2. Methodological Framework

4. RESULTS

Results are presented in the following way. First, the current usage and existing capacities of DDA and MCD are analyzed from primary data collected. Second, analysis reveals the agencies collective understandings or awareness about 3D concepts in relation to their work. Finally, the results about the potential benefits are presented based on summarized responses and observations of authors.

The primary data analysis helps to find out the current usage of 3D representation in activities performed by DDA and MCD. Using van Oosterom's (2013) work as an analytical framework, the case study results in Table 1 reveal that at the initial stage of land acquisition and zonal level planning, 3D representation is not put into practice, but during the design phase for new spatial objects such as buildings, both 2D to 3D graphic representations are generated. Registration of spatial objects and use permits do not have 3D graphic representations, but by-laws and permissions define 3D rights and restrictions in textual format. Engineering surveys, using total stations, are used to record data, but that is currently stored and analyzed in 2D. However, 2D CAD drawings are created with 3D positions marked as annotations. Checks and validations of submitted data involves the third dimension, as mentioned in text format. Information related to spatial units is also disseminated usually in 2D but also in 3D as per requirement.

Table 1. Current Practices related to 3D Representation in DDA and MCD Activities

Activities (as per Peter van Oosterom, 2013)	Delhi Development Authority	Municipal Corporation of Delhi
Develop and register zoning plans in 3D.	No	No
Register (public law) restrictions in 3D	No	It exists in by-laws text but not in 3D Graphics
Design new spatial units/objects in 3D	Yes	Mostly 2D designs except when submitting to a particular agency
Acquire appropriate land/space in 3D	No	No
Request and provide (after check) permits in 3D	Not done in DDA and Other Departments	Permits are given in text
Survey and measure spatial units/objects (before or after construction) in 3D	Total Station Surveys now in Practice	Survey drawings mark 3D positions
Submit associated rights (RR)/parties and their spatial units in 3D	No	N/A
Validate and check submitted data (and register if accepted) in 3D	No	3D is mentioned in text form
Store and analyze the spatial units in 3D	Unavailable special tools and trained manpower in DDA	3D is mentioned in annotation form in 2D Cad files
Disseminate, visualize and use the spatial units information in 3D	No but may be in future	Dissemination of the spatial units information in 3D as required.

Furthering the investigation beyond this analytical framework, the respondents were asked to give opinions about existing technical and financial capacity, administrative understanding and availability of skilled human resources in relation to 3D representation.

Figure 3 depicts the responses about organizational readiness to adopt a 3D representation approach in terms of technical capacity, financial capacity, skilled human resources, administrative / strategic understanding. The two organizations seems to have low to moderate levels of technical capacity, except for some newcomers. Training is required to develop human resources skills. On the other hand, many respondents expressed that financial capacity exists currently in the two organizations, so as to adopt 3D representation concept in practice. Understanding of the 3D representation concept exists to some extent at administrative and strategic levels. As a whole for the organization, it exists in low or moderate form.

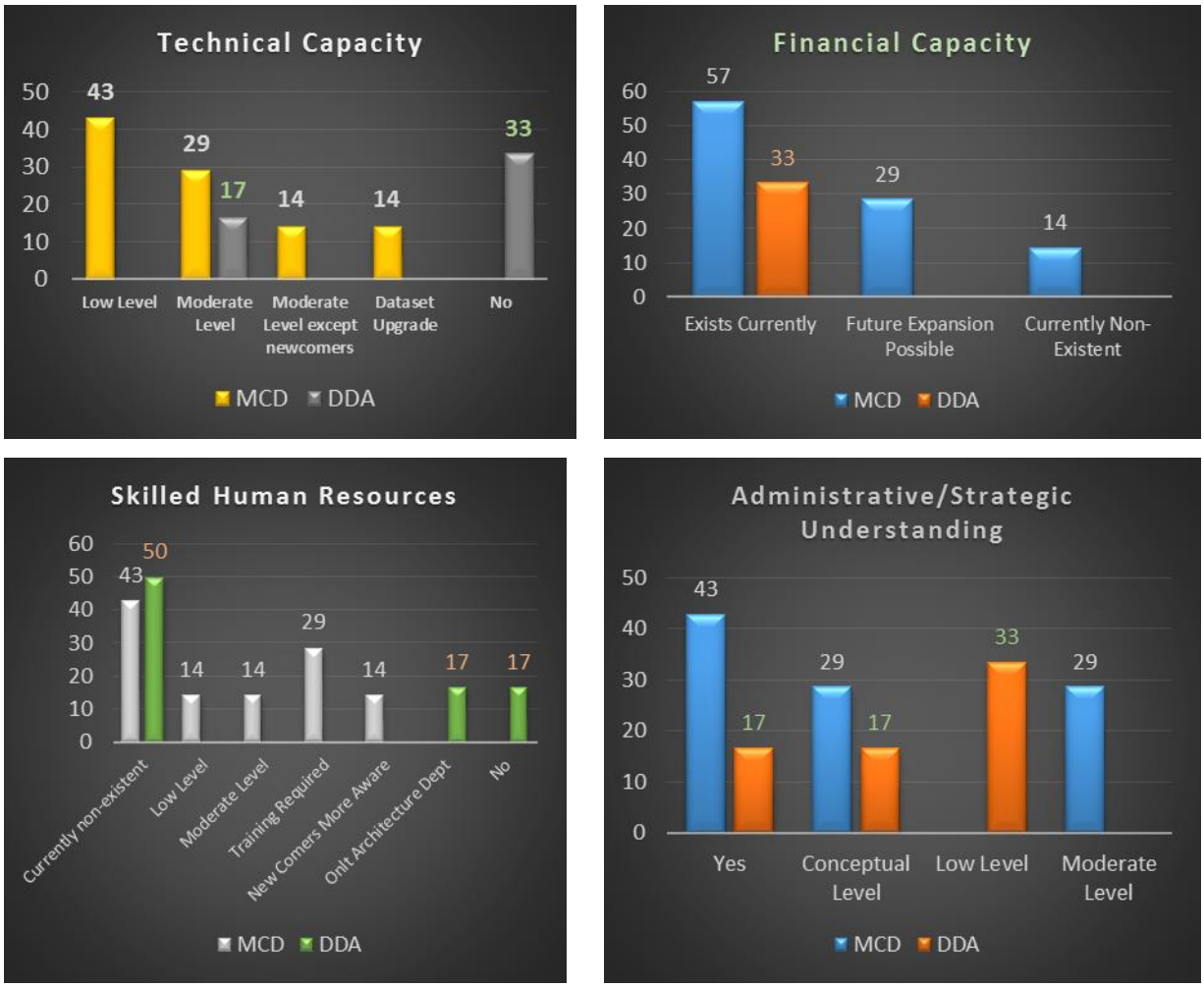

Figure 3. (a) Technical Capacity; (b) Financial Capacity; (c) Skilled Human Resources; (d) Administrative / Strategic Understanding (in percentages)

Statistical analysis of survey questions also revealed the agencies understanding or awareness about 3D concepts in relation to their work. Respondents have linked, as shown in Figure 4, it with physical structures as well as their layouts designs or technical estimates of works. These concepts are hardly associated with project schemes or cadastral features. Interestingly, some have linked 3D concepts to the understanding of 3D volumetric data. This understanding about linking the concepts with designs, volumes or technical estimates is evident with their understanding or awareness of 3D design software, like CAD or new industry standards in the form of BIM (refer to Figure 5). Despite being the agencies involved with land planning, development and management, the concept of 3D has not yet extended to 3D cadastre. As depicted in Figure 6, the majority of the respondents are not aware of it. However, some have linked 3D cadastre with 3D tenure in multi-story buildings, physical linkages of utility networks, and with surface or sub-surface parcels. Still following the traditional role of land cadastre with revenue generation, some have linked 3D cadastre concept with property taxation.

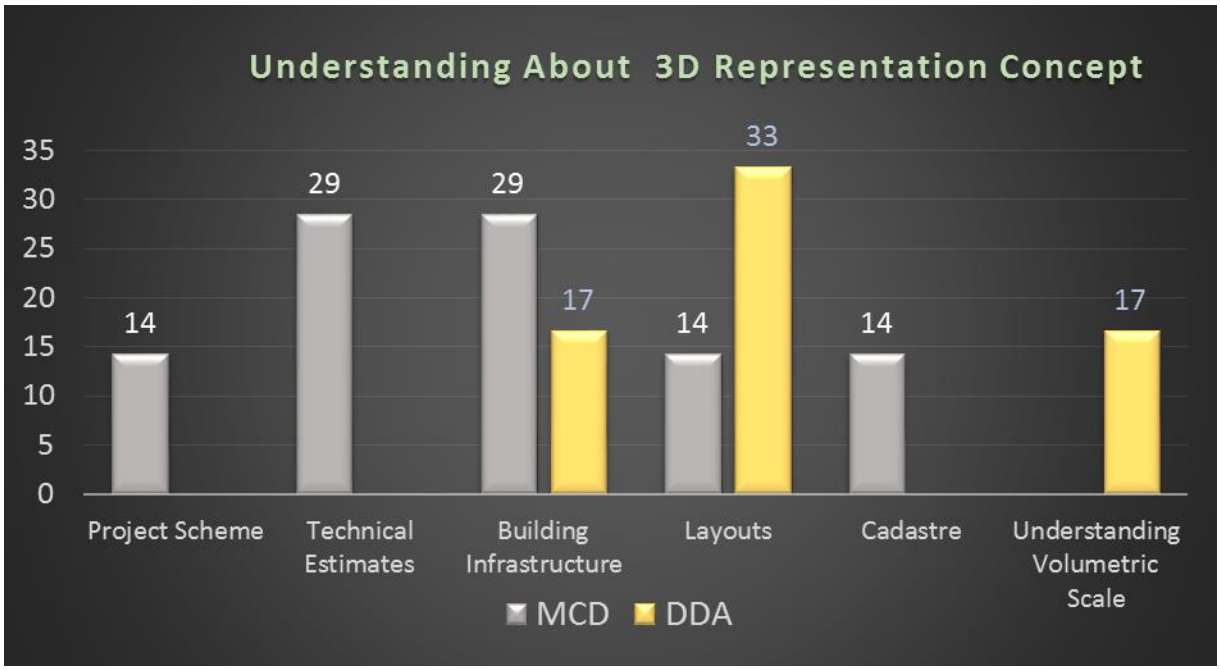

Figure 4. Current understanding about 3D representation in MCD and MCD (in percentages)

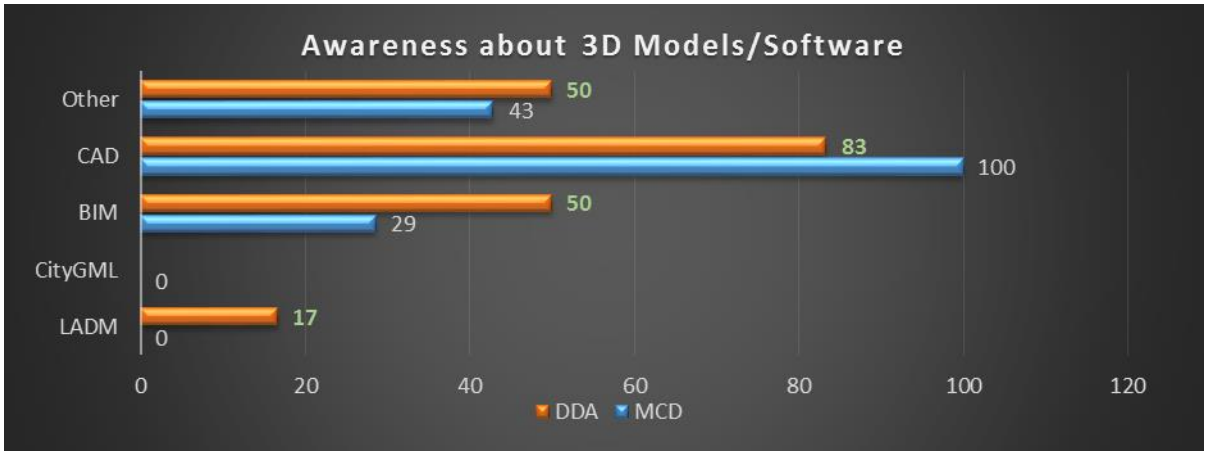

Figure 5. Current understanding of 3D Software in MCD and DDA (in percentages)

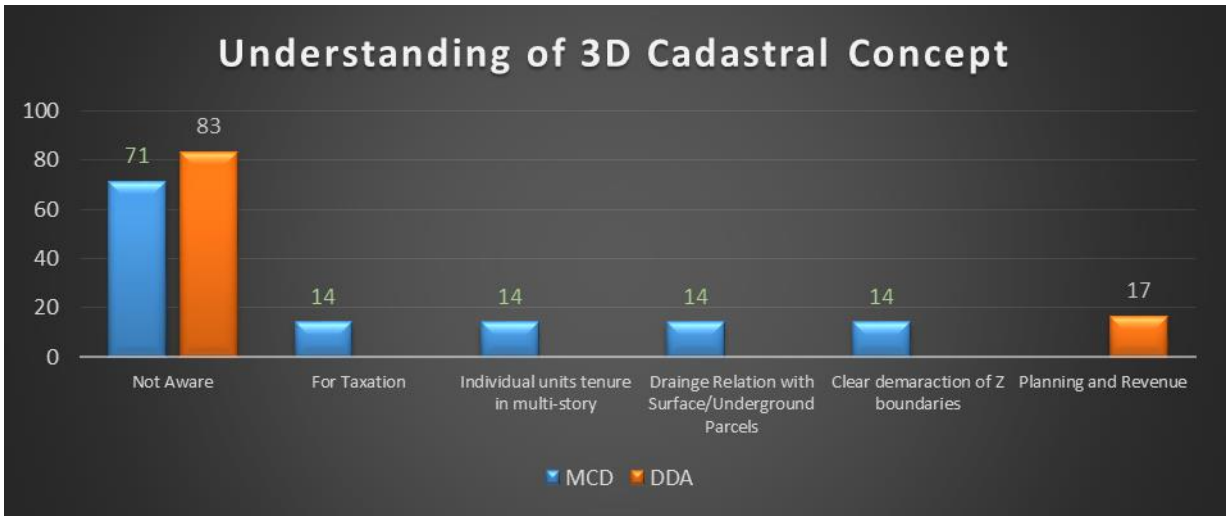

Figure 6. Current understanding of 3D Cadastral Concept in MCD and DDA (in percentages)

Further analysis answers the question about the areas having potential for DDA and MCD in context of 3D representation and cadastre. Respondents associated the benefits, as shown in Figure 7, not only with the obvious use for 3D visualization such as z boundaries demarcation, the Floor Area Ratio (Ratio of building's total floor area to the area of land plot), but also with the quality checking of underground utility network and identification of assets location in multi-storied infrastructure. Some other benefits are plot allotments, identifying property tax defaulters, factory licensing, and identification of unauthorized construction, hindrance and reduction in ambiguity about surroundings.

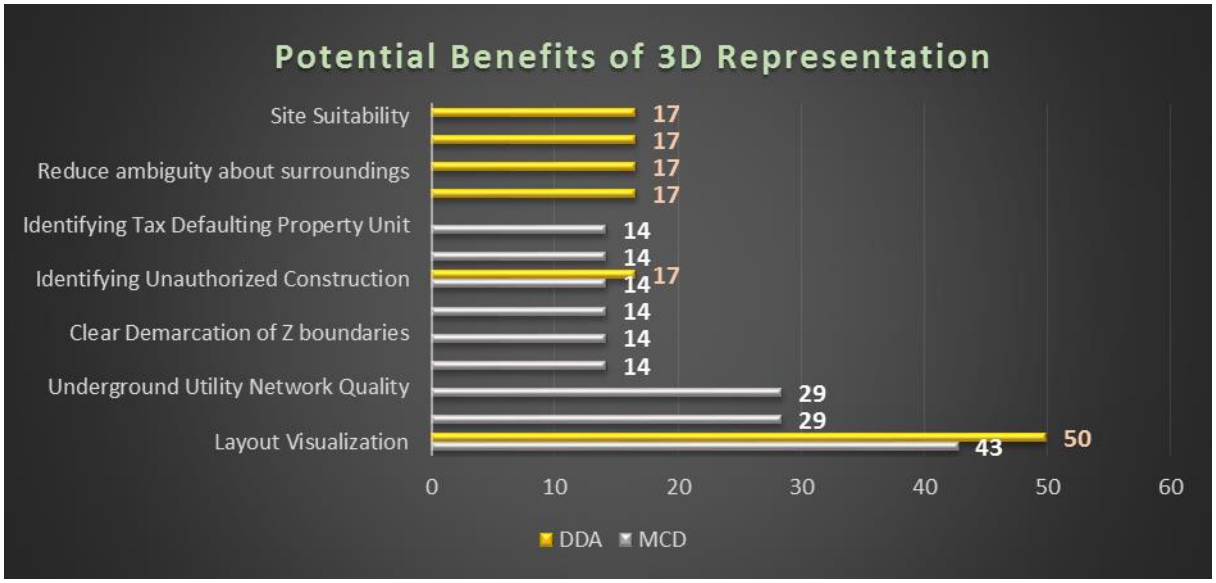

Figure 7. Potential Benefits of 3D Representation for MCD and DDA (in percentages)

5. DISCUSSION

Delhi with its growing population and infrastructure is looking for alternatives for using and governing space. One alternative is to grow vertically with 3D developments. With development of complex 3D structures, a socio-economic need has been generated to identify and demarcate clearly the tenure rights in multi-story buildings with individual and common ownership claims.

DDA and MCD are the two key land planning, development and management agencies in Delhi. Due to the very nature of their work, they are functionally related in many ways. Thus it is imperative that while discussing the 3D representation options for Delhi, the current practices, vision and potential benefits or need to adopt the 3D representation of these two organizations is explored.

To begin with international standard approaches for adopting 3D representations and cadastre were described in the context of development of infrastructure in Delhi especially high-rise buildings. It is apparent that LADM, an ISO 19152 as a conceptual model, can provide predefined spatial and administrative information components with enough flexibility to adopt a 3D representation and 3D cadastre approach. It has defined methods having 3D primitives to compute and create 3D volumes which could be important for demarcating boundaries and defining RRRs in 3D structures.

In addition to the adoption of this conceptual model, the organizations would need to have standard data model and exchange format which can capture 3D alterations of landscape on city level. CityGML as an open standard allow the data structuring with different Level of Details (LoD) for capturing the infrastructure development. This standard allows to digitally describe and store the common features related to buildings and streets along with their relationships. The city wide database, with flexibility to introduce new extensions, classes and attributes, could be customized by different organizations involved in land planning and management.

With Building Information Management (BIM) models, the citywide database could be focused for individual complex buildings to facilitate multi-disciplinary coordination and integrate 3D design, analysis, cost estimating and construction scheduling. This kind of model can in fact bridge the time gap between planning and development of infrastructure by DDA and setting up municipal regulations at a later stage by MCD, such as maintenance or monitoring schedules. Such models can allow the two organizations to work in an integrated manner in context of complex infrastructure. Both organizations are already having a common ground in the form of Computer Aided Design (CAD) software based digital files used by the respective departments such as Architecture in each organization.

Whilst the above standards and tools appear relevant and applicable to the Delhi context, expectations for short and medium term implementation should be tempered. The results obtained from primary data collected on current practices related to 3D representation and 3D cadaster in DDA and MCD activities show quite some disparity exists: existing 3D

representations in graphic manner at a very limited scale for design or visualization purposes, and to some greater extent in non-graphical or textual manner, in documents or database related to 3D rights and restrictions. Albeit, during the interviews, officials of DDA and MCD associated their understanding on 3D representation and cadastral concepts with scheme conceptualization level to layout design, as well as for a more complex purposes of volume calculation.

Moreover, several benefits are foreseen by the officials ranging from Floor Area Ratio (FAR) measurement or visualization, clear demarcation of Z boundaries, quality checks of underground utility networks, location of assets in multi-story infrastructure, as well as identification of unauthorized construction. These benefits are of operational level but could have evident impact in creating policy level changes.

In terms of organizational capacity assessment, financial capacity exists to adapt 3D representation for activities at different levels but technical capacity and skilled human resources are assessed as mostly non-existent or low levels. Many respondents agreed that at administrative or strategic level there is an understanding about the 3D representation concept, however it exists only at moderate or low levels. Many in EDMC are of the opinion that understandings are only at a conceptual level only. Regarding understanding 3D cadastral concepts, most of the respondents acknowledged no knowledge. In DDA, some respondents agreed that it would be useful for planning and revenue purposes. Similar responses were received regarding awareness about 3D models or software which emphasize the need to spread the knowledge about these models or concepts on organizational levels.

In addition, in a more promising vein, with 3D representation of physical and legal spaces, many of the functions of DDA and MCD are identified as being able to be enhanced:

1. Enhancing Engineering Works Accuracy

All types of engineering works performed by DDA, be they for new developments or repair and regular maintenance performed by MCD, often require 3D visualization of boundaries, volumes and spaces. Currently, the demarcated boundaries or volumes are not fully represented in 3D and many a times, paper copies are used. 3D representation of properties could enable engineers and planners of the respective organizations to visualize the dimensions of property and perform their job with more certainty. For example, in the case of adjoining boundaries in densely populated colonies, which is often the case in Delhi, a 3D representation of boundaries would allow engineers to approve a building layout plan submitted by a landowner to construct multi-story building. They can easily check whether the submitted plan is as per the rules and do not encroach adjacent properties.

2. Efficient Infrastructure Planning and Designing

With new high rise redevelopments and other complex infrastructure emerging, the risk of errors and resource inefficiency will increase. Costly mistakes can be avoided during construction by early adoption of 3D representation in the planning and design phase (Chou, 2017; Autodesk, 2018.). 3D representation will allow the designers to develop designs which can communicate the planned structures with much more realistic impression. Using better

information and preview available through these designs, plans can be made with higher accuracy, especially regarding complex and dense structures with multiple ownership and management.

3. International Compatibility of Data

A complete dataset in terms of three spatial dimensions, will allow compatibility with proper international standards of 3D representation and cadaster. Following international database management standards will allow to record all the necessary features, attributes and linkages related to infrastructure. The compatible standards will make it easy to adopt any new developments in the international standards if found suitable for Delhi case. This will enable the DDA and MCD officials to maintain proper records in a synchronized manner to cover all the necessary characteristics of infrastructural features for understanding their potential linkages with external and internal factors.

4. Clear Demarcation of 3D Spaces and Clarity of 3D Tenure Claims

Delhi is witness to an upcoming World Trade Centre and other large residential developments of high rise in nature. New complexes can have clear demarcation of separate entities in multi-dimensional and multi-story structures owned by different parties. Thus it will help to determine the physico-legal spaces of ownership and lease or easement rights giving more clarity to tenure claims.

5. Enhanced Taxation Accuracy

Delhi is generating a lot of physical space in multi-floor complexes which can be a huge source of revenue through sale or rental and further through annual taxation for DDA and MCD. With clarity in tenure claims over land or property in complex structures, for both exclusive and common, authorities can determine taxation with more accuracy.

6. Higher Certainty in Insurance Premium and Assessments

Property insurers and economic valuators can have more certainty in determining respective premiums and valuation assessment of such complex 3D structures.

7. Efficient Disaster Response and Compensation Claim Verification

Delhi is prone to earthquakes as it falls in Zone IV. East Delhi and other parts of Delhi falling in Yamuna river floodplain are prone to flooding which can cause severe damage to infrastructure. Delhi has a significant number of unauthorized colonies with large number of multi-story constructions built without following structural engineering norms. Such colonies and old Delhi area are similar in terms of population density, mixed landuse, encroachments, and illegal constructions with additional floors or space divisions. These areas are prone to huge fires as well as terrorist attacks as seen often in the past. With 3D representations, better and quick responses can be generated. In disaster recovery phase, authorities can always verify the claims to compensation with higher accuracy based on 3D records available.

The above mentioned benefits and opportunities aside, any strategy aimed at transitioning to a 3D representation and cadastral environment, clearly requires deeper analysis on legal, financial, and socio-economic constraints. The cost of such a system played off against the

benefits it would derive for *all* citizens requires scrutiny in particular. Implementation issues also require examination, and in a diverse and dynamic context such as Delhi, it is likely that piloted, phased, or context specific roll out (e.g. trialing on specific developments), would be the most realistic approach. In the short term, awareness raising and development of extended use case descriptions appear the most pressing needs.

8. CONCLUSION AND RECOMMENDATIONS

Like many contexts, the idea of transforming 2D management of legal property into the 3D domain remains in its infancy in Delhi. That said, the concept of 3D representations could enable initiatives towards 3D cadastre in the rapidly expanding city with its developing complex infrastructure. DDA and MCD, being the primary agencies responsible for land planning, development and management, require capturing this infrastructure growth in third dimension. The reviewed conceptual models and software as international standards have been explored in the case context of Delhi. Although the understanding of 3D representation and its current usage is quite limited in an explicit manner in DDA and MCD, the primary data analysis echoed the requirement of 3D representation for visualization, planning and designing of infrastructure as well as relevant decision making process. That said, the concept of 3D cadastre is almost absent from these organizations.

It is recommended to emphasize the need for the adoption of 3D representation in such organizations in Delhi to have timely interventions for planning, development and management of city infrastructure, with a participatory approach and sustainable mindset. This will allow to develop more proactive systems with responsible city development and management organizations, executing responsibilities in a transparent manner.

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BIOGRAPHICAL NOTES

Tarun Ghawana has an M.Sc in GIS with Specialization in natural resource management from International Institute of Geoinformation Science and Earth Observation, Netherlands. He has worked as a GIS expert in India, Netherlands and Germany on natural resources management projects with academia as well as private consultancies. His area of interest includes land administration, disaster management and GIS based spatial analysis. Currently, he is working as GIS Consultant with Integrated Spatial Analytics Consultants, a multidisciplinary firm which is based in India. Previously, he was the Dissertation Coordinator, Co-Supervisor and Visiting Faculty for Disaster Management Centre at a State university of Delhi. He was also involved with feasibility study, systems analysis, programme management and content management at a bilateral Centre of Indian and French government for promoting advance research in S and T. He is programme and scientific committee member of international conferences on smart cities and 3D spatial information science.

Rohan Bennett is an Associate Professor with the Swinburne Business School. He is the Research Director for the Department of Business Technology and Entrepreneurship and was previously Discipline Leader for Information Systems. Prior to joining Swinburne, he was the Director of the School for Land Administration Studies and an Associate Professor with the University of Twente, ITC Faculty, Netherlands. He led and coordinated 'its4land', a 4-year 4M EU European Commission H2020 project (its4land.com). He holds a PhD from the University of Melbourne Australia. Rohan works at the intersection of information systems, geospatial science, innovation, and responsible development.

Jaap Zevenbergen is professor of land administration and land management at the Faculty ITC of the University of Twente since 2008. Before that he worked at TU Delft, where he also received his MSc in Geodetic Engineering and his PhD. He further holds a LLM in Dutch Law from the University of Leiden. Among others he served as member on behalf of the training and research institutions of the Global Land Tool Network for two 2 year terms, and was Programme Director of the MSc Geoinformation Science and Earth Observation at ITC. Currently he is associate editor of the journal Land Use Policy and Head of Deparment PGM within ITC. He acts and acted as supervisor for 30 PhD’s, and as (external) reviewer of another 40+.

Pradeep Khandelwal has an M.Tech in Environmental Engineering and Science from Indian Institute of Technology, Delhi. He has done B.Tech in Civil Engineering. He has been working with Municipal Corporation of Delhi for 33 years. He has a wide range of experience in urban infrastructure projects namely transport sector, education sector and road sector. He has been involved in designing as well as execution of many such projects. He also undertook training for three months in Japan on Planning and Development of Urban Facilities. He has been a pioneer in planning and supervision of many waste management projects in Delhi. Under his expertise, drainage schemes, solid waste management, waste to energy, segregation of garbage etc have been implemented in National Capital Territory of Delhi. Currently, he is working as Chief Engineer in East Delhi Municipal Corporation

Subu Rahman currently serving as Commissioner (Land Disposal), Delhi Development Authority, Ministry of Housing and Urban Affairs, Government of India. Subu Rahman is an Indian Audit and Accounts Services 2001 batch officer which is under the Comptroller and Auditor General of India. After graduating from University of Kerala, he has done his LLB from University of Delhi, Post graduation from Indian Institute of Management, Bangalore (IIMB) in addition to various courses from London school of Economics (LSE), Maxwell school of citizenship and public affairs Syracuse University, Goldman school of Public Policy University of California, Berkeley. He has a wide range of experience working in Govt. of India in various capacities including in Ministry of Defence, Indian Audit & Accounts Department, Audit related works in World Health Organisation Hqrs, International Organisation for Migrants in Kuala Lumpur, Geneva, Cairo, Khartoum, Jordan etc. He was also the Nodal Officer and Director (Report) of Performance Audit on the issue of License and Allocation of 2G spectrum. It was his Brain Child to Audit the correctness of revenue to the Government in the sharing of spectrum by the Private telecom service providers. He also chaired the committee to bring in norms and guidelines for Digitization of all Accounts & Entitlements offices of all states in India. Currently along with his present work he is on a project implementation to bring transparency to Delhi Development Authority (DDA) by the name IDLI system (Interactive Disposal of Land Information System). He is also member of IIPA, IPAI, etc. Camp Leader of the project which won the Indira Vrikshamitra Award (Green Oscar of India) from Govt of India in 1991.

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