Capturing Legal and Physical Boundary Differences in 3D Space – A Case Study of Trinidad and Tobago

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Key words: Legal, Boundary, 3D

SUMMARY

Technology has simplified the construction of a 3D cadastre by allowing rapid, remote capture of the data required for the graphic components of the system. Research into using 3D information generated from laser scanning, LiDAr and satellite imagery, and aerial photography for Building Information Management (BIM) has advanced considerably over the last few years. These methods work by capturing man-made physical features such as walls or fences that coincide with legal boundaries or by capturing natural physical phenomena such as high water marks or river banks that are directly considered to be legal boundaries. Although the acquisition of some of this technology is very costly, the technology speeds up the process significantly beyond the time traditional labour intensive methods would require. However, in many jurisdictions there are several instances where the man-made physical boundaries do not coincide with the legal boundary or where the legal or accepted boundary has no physical expression in natural phenomena. This provides difficulties for the construction of 3D cadastres on land as well as in the marine environment. In these instances there must be alternatives to determining the location of the legal boundary. Where these intangible or obscured boundaries must be directly surveyed, the cost and labour required to construct the cadastre can render its development out of reach especially since the acquisition of the attribute data such as the nature of the interests and the identification of the interest holders also cannot be done remotely. This paper investigates the number of instances where the physical structures do not define the legal boundary and therefore the number of instances where additional surveying on the ground may be required to connect the legal boundary location to the physical expression of the boundary. The case study is Trinidad and Tobago. A sample area was used to determine what the various boundary types are and what methods can be used to acquire these data and construct the 3D cadastre in the most effective and efficient way possible.

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1. INTRODUCTION

3D cadastres are the information systems to which countries should aspire for more efficiently managing land rights, since they capture the reality of how rights are held and used in more densely populated urban and peri-urban environments. However, their construction and maintenance requires vast quantities of data. Technology has simplified the acquisition of some of that data by allowing rapid, remote capture. Research into using 3D information generated from laser scanning, LIDAR and satellite imagery, and aerial photography for Building Information Management (BIM) has advanced considerably over the last few years. These methods capture the locations of tangible, man-made physical features such as walls or fences that coincide with general boundaries or can be used as surrogates for fixed legal boundaries. They can also capture natural physical phenomena such as high water marks or river banks that are directly considered to be legal general boundaries, even though they are ambulatory (moveable).

Although the acquisition of some of this remote sensing technology is very costly, the technology speeds up the process significantly beyond the time that traditional labour intensive direct survey methods would require. However, in many jurisdictions there are several instances where the man-made physical boundaries do not coincide with and are not considered to be the legal boundary or where the legal or accepted boundary has no physical expression in natural phenomena. This provides difficulties for the construction of 3D cadastres on land as well as in the marine environment. In these instances there must be alternatives to determining the location of the legal boundary. This could make the cost and labour required to construct the cadastre out of reach especially since the acquisition of the attribute data such as the nature of the interests and the identification of the interest holders cannot be done remotely.

It is required to be determined in what proportion is the data that can be acquired quickly to the data that must use the slower methods. There must also be a determination of the relative costs of the different data acquisition processes so that plans can be made for construction of the 3D cadastre in the most efficient and effective way possible.

The aim of this paper is to investigate the relative costs and times required for acquisition of the necessary data for the construction of a 3D cadastre by referencing a sample area in Trinidad and Tobago and the procedure for moving from the current status of its cadastre to a 3D cadastre. The objectives are to:

- determine the different types of boundaries that exist in the cadastre in Trinidad and Tobago;

- determine the methodologies that can most efficiently acquire the different boundaries for the 3D cadastre in Trinidad and Tobago;
- determine the relative amounts of each boundary and each methodology that would provide the most efficient way of creating the 3D cadastre based on the case study sample area.

2. METHODOLOGY

To meet the aim of the paper, a sample area was selected in the case study country that had the characteristics that required a 3D cadastre for visualising the rights. The sample area selected was a portion of the capital city of Port of Spain, which is representative of the densest occupation of buildings and overlapping of rights, restrictions and responsibilities. An assessment was then done of the different ownership rights contained within the sample area and the required methodologies for acquiring the boundaries to those rights that would be needed. A conclusion was then drawn on the total amount of resources required to construct the 3D cadastre for the city. On the basis of this conclusion, recommendations were made on the procedure for completion of the process. There was no need to focus on the actual procedures and functionalities of the technologies since the aim was primarily on determining the relative need for different technologies for different boundary types.

3. BACKGROUND

In recognition of the increasing urbanisation that is occurring in the world in most countries, many researchers have recommended the construction of 3D cadastres (Rajabifard, 2014; El-Mekawy, Paasch and Paulsson, 2014; Kalantari and Rajabifard ,2014). The next United Nations (UN) Conference on Housing and Sustainable Urban Development (HABITAT III), which is held only every 20 years, and which will be held in Quito, Ecuador, 17-20 October 2016, proposes to focus on sustainable development of towns, cities and other human settlements, both rural and urban. The expectation of the outcome is what is being called a New Urban Agenda, which will set in motion plans to manage the urbanisation of the next two decades. These plans will not be possible without a supportive land administration system that focuses on the urban and urbanising environments. Small Island Developing States (SIDS), such as Trinidad and Tobago (see Figure 1) are especially in need of such land administration systems as a result of the need to manage and equitably allocate small areas of land to relatively dense populations. It is recognised that 3D cadastres should focus on urban and urbanising environments for cost effectiveness (Kalantari and Rajabifard, 2014; Griffith-Charles and Edwards, 2014) since rural and agricultural areas and areas of low elevation construction do not contain significant numbers of overlapping and interlocking land units with differentiated rights. However, even within urban and urbanising areas, differentiations should be made regarding which high rise and subterranean land units need to be spatially defined internally and externally for even greater cost effectiveness (Griffith-Charles and Sutherland, 2013).

Figure 1. Trinidad and Tobago (Source: Ezilon.com)

4. LITERATURE

4.1 Boundary systems

Two types of boundaries are usually defined; fixed boundaries and general boundaries. Fixed boundaries are mathematically defined by coordinates of the ends of the boundary lines, or as the vectors of the boundary lines themselves, which are more specifically described by bearings and distances. Fixed boundaries are therefore intangible and invisible. They can be very precisely or imprecisely defined depending on the legal specifications of the particular jurisdiction. General boundaries, however, are usually defined in reference to tangible physical features. They may be as unspecific as stating that the feature itself, the wall or fence, for example, is the boundary, or as specific as stating where on the feature the boundary line is such as the centre line of the wall or the inside or outside of the wall. The precision of general boundaries may therefore be as variable as fixed boundaries but usually fixed boundaries are defined to be more precise than general boundaries. The type of boundary system being used in a particular jurisdiction has implications for what type of methodology can be used to capture the graphics for the 3D cadastre. For general boundaries, images or measurement of the physical features can provide data to be put directly into the system. For fixed boundaries, computations and dimensions are required to be put into the system irrespective of the images or the locations of the features.

Boundaries are legally established by a process of definition, delineation and demarcation, whether they are fixed or general. The demarcation process determines whether the boundaries are defined on the ground by boundary markers or physical features. Boundary markers cannot be seen on imagery while general boundaries can. For constructing a 3D cadastre, imagery can be used to construct boundaries for jurisdictions where general boundaries are used but can only be used to construct boundaries in fixed boundary jurisdictions where the relationship between the fixed boundary and the physical features are defined in law, are known or can be measured on the ground or in the imagery. In jurisdictions where a combination of different boundary systems are used, the boundaries should be categorised into the different types for standardised treatment for acquisition and entering into the database. El-Mekawy & Östman, (2012) conclude that, for the purposes of constructing a 3D cadastre, all boundaries can be encompassed in groups for "Building Elements Surfaces," "Digging Surfaces," "Protecting Area Surfaces," and "Real Estate Boundary Surfaces" (El-Mekawy, Paasch, and Paulsson, 2014; 2015). They define the Building Elements Surfaces as physical building features that coincide with boundaries such as apartment walls. Digging Surfaces are also physical building features but are those that occur in a subsurface location such as tunnels and garages. Protecting Area Surfaces are boundaries to planning restrictions such as setbacks and reserves. Real Estate Boundary Surfaces are extrusions of intangible boundary lines such as those that are the outer limits of surface parcels. The Building Elements Surfaces and the Digging Surfaces are therefore those tangible surfaces that can be captured using imagery while the Protecting Area Surfaces and the Real Estate Boundary Surfaces are intangible and would have to be mathematically constructed in the database or surveyed on the ground and then entered on the database depending on the precision required for the 3D cadastre. Since urban areas are the most highly valued land in the country and land units tend to be small, required precisions for defining boundaries in these areas tend to be very high.

4.2 Technologies for data capture

Various technologies have come into existence that speed up the process of capturing data for a 3D cadastre. Different methodologies are required for different types of boundaries. Building Information Models/Modelling or BIM, can provide useful information for the construction of a 3D cadastre (Rajabifard 2014). They may, however, present a measure of overkill for the 3D cadastre as they are primarily concerned with visualisation of all physical elements of a building with attributes necessary for management of design and maintenance of facilities. Rajabifard (2014) envisages a role for BIM in construction of 3D cadastres but this can only happen with a filtering of the elements in the BIM to identify only those components necessary for boundary delineation and discarding the rest. Kumar et al (2015) provide an investigation of how the required building data can be filtered from vegetative cover and incidental street furniture for large scale LiDAR data and this is necessary since the LiDAR produces vast amounts of point clouds that must be managed and manipulated to obtain relevant data.

LiDAR, similarly to BIM, can speedily acquire large quantities of data but only where the data to be acquired exceeds the basic amount required for adequate definition of the boundaries otherwise the technology becomes inefficient. Pouliot and Vasseur (2014) found that LiDAR performed better than the Distancemeter for collecting large amounts of parcel boundary data both inside and outside of apartments.

4.3 Methodologies available

New approaches to constructing cadastres such as Fit for Purpose and STDM methodologies can assist in determining alternatives which may include reduced precision visualisation of boundaries or the use of 2D parcel polygons as mere buckets to house more detailed 3D survey plans that can be presented in a window on screen along with the legal attributes. Lower precisions and innovative methodologies may be difficult for professionals to adopt for various reasons (Griffith-Charles et al 2015) however, cadastres do not all have legal status many jurisdictions so can be attempted nonetheless.

Duarte de Almeida et al (2014) discuss the use of Volunteered Geographic Information (VGI) as a methodology for collection of data to construct the 3D cadastre. The VGI is expressed at five levels of data validity but since the purpose of cadastres is to provide evidence of land rights, a preponderance of data corroborates itself. It can be envisaged that purchasers can place value on property based on vendor supplied photographs of internal and external extent, which can be kept in the 3D cadastre.

The case study of Trinidad and Tobago is used to examine the specific instances where the legal boundaries would need to be surveyed as they would differ from the physical expression of the boundary.

5. CASE STUDY – TRINIDAD AND TOBAGO

5.1 Boundary system

The Trinidad and Tobago cadastral system uses fixed boundaries which means that boundaries are invisible, intangible and defined by measurements of bearing and distances indicating the dimensions of the boundary between two successive corner points. The corner points illustrate change of direction. An example of this in practice is shown in Figure 2 (below) which shows a portion of the survey plan where the legal boundary lines are defined but have no expression in reality as shown in Figure 3 (below) where the cadastre is superimposed on the imagery of the ground. This situation is most problematic for the construction and verification of the cadastre where occupation and development has not occurred.

General boundary systems, such as that in use in the UK for example, conversely, use physical features such as walls, hedges, ditches, fences, roads, and streams, and the foreshore to define limits of land rights. Some specific general boundaries are accepted as legal boundaries in Trinidad and Tobago and these are the banks of streams and the high water line of the foreshore. In most instances the physical features of walls, and fences coincide to some level of precision with the legal boundaries or are related to the legal boundaries so that the legal boundaries can be implied from the physical features. This occurs for example, where the boundary lies at the centre of a party wall. Figure 4 (below) shows an example where boundaries conform to the occupation on the ground and are expressed by walls surrounding each land parcel.

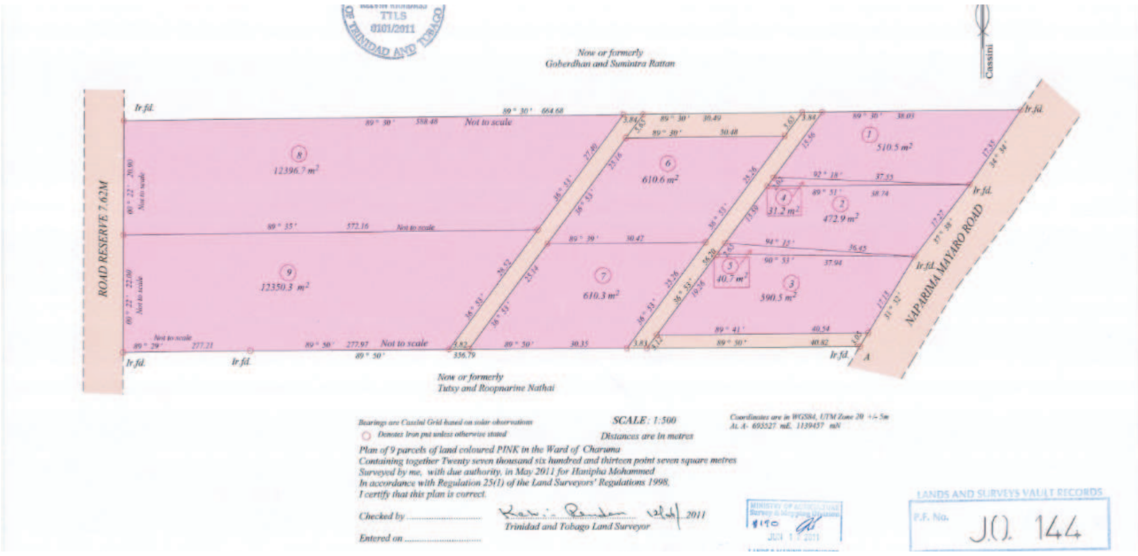

Figure 2. Survey plan of parcels of land defined by legal boundary lines

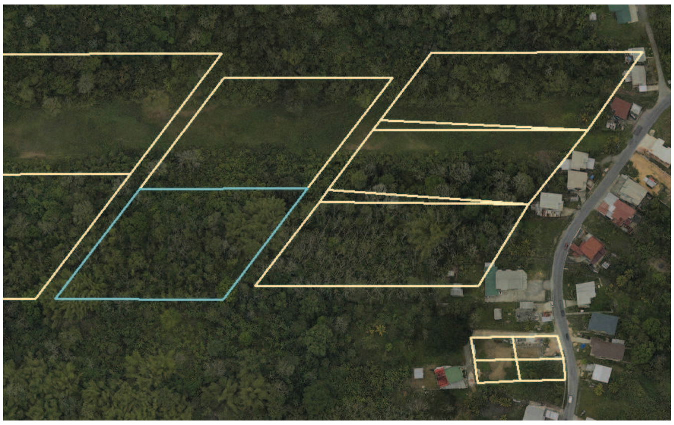

Figure 3. Cadastral boundaries of undeveloped parcels superimposed on image of the ground

General boundary systems, such as that in use in the UK for example, conversely, use physical features such as walls, hedges, ditches, fences, roads, and streams, and the foreshore to define limits of land rights. Some specific general boundaries are accepted as legal boundaries in Trinidad and Tobago and these are the banks of streams and the high water line of the foreshore. In most instances the physical features of walls, and fences coincide to some level of precision with the legal boundaries or are related to the legal boundaries so that the legal boundaries can be implied from the physical features. This occurs for example, where the boundary lies at the centre of a party wall. Figure 4 (below) shows an example where boundaries conform to the occupation on the ground and are expressed by walls surrounding each land parcel.

Figure 4. Legal boundaries conforming to physical boundaries of walls

In the case study sample area of Port of Spain, the capital city of Trinidad and Tobago, complexities in legal boundaries exist, such as that shown in Figure 5 where a walkway above the street creates overlapping land rights that cannot be easily shown on the 2D cadastre.

Figure 5. Example of above ground complexity in land rights

5.2 Sample area of Port of Spain

A small area of Port of Spain comprising 3 blocks was selected to demonstrate the procedure for creating the 3D cadastre and the need for different approaches. Figure 6 shows a LiDAR cityscape of Port of Spain with several multi-storey buildings while Figure 7 shows a LiDAR image of the sample area. The LiDAR data is available and can be used to develop a full 3D topographic cityscape, however, that would be unnecessarily wasteful of resources if it is not legally required or does not reflect the cadastral boundaries.

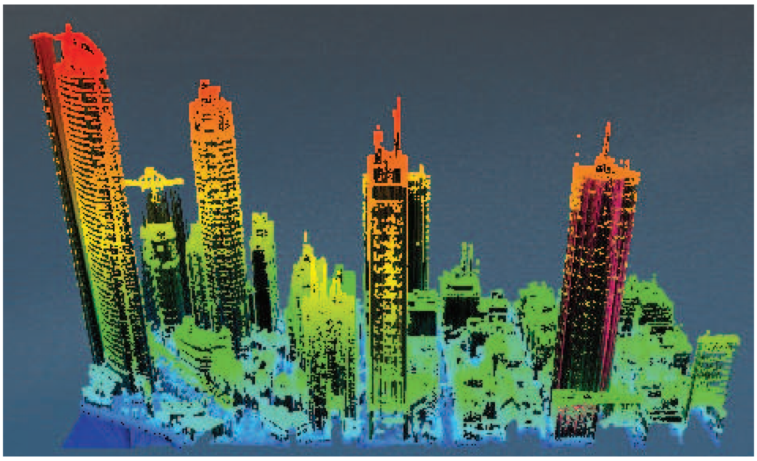

Figure 6. LiDAR Cityscape of part of Port of Spain

Figure 7. LiDAR image of selected area in Port of Spain

The sample area of 3 blocks contain 16 individual land units or parcels, that is, areas of homogenous title. The sample contains 3 multi storey buildings and 16 additional single or two storied buildings. However 2 of those 3 multi-storey buildings belong to the state and house government ministries and their offices and staff. There is therefore no need to show the building in these situations since the parcel includes the building and the surrounding air space. The boundaries of these 15 parcels should therefore be digitised from the survey plans that indicate the intangible dimensions of the extents of the parcels. The boundaries can then be extruded upwards to a standardised height that reflects planning restrictions. The third multi-storied building is a private commercial building that includes several floors and many leased office spaces.

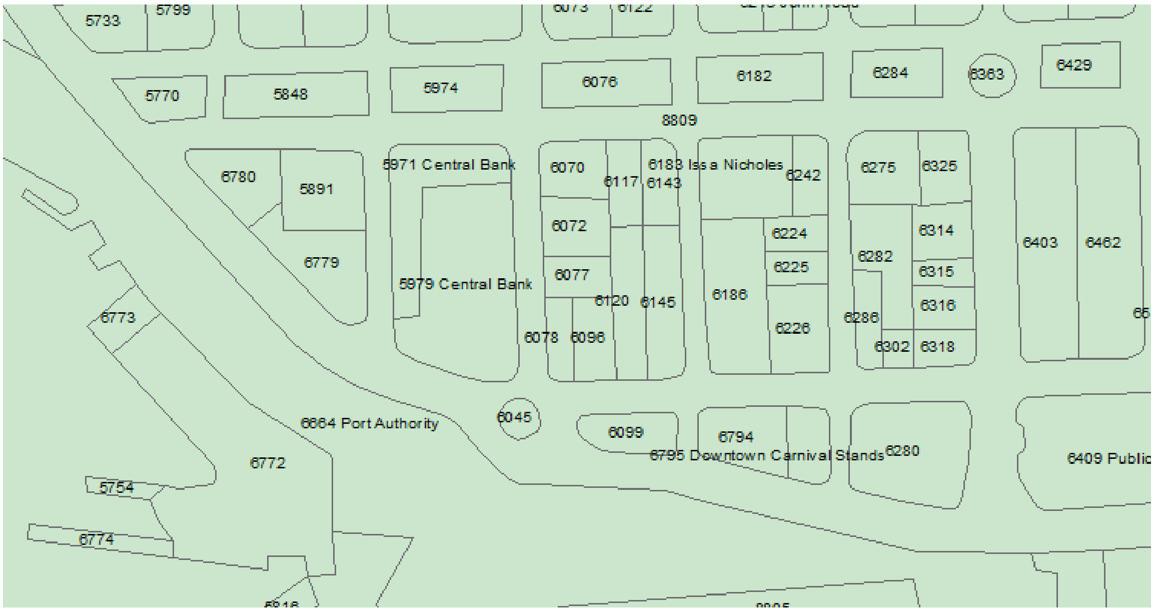

Figure 8. Detail of the 2D cadastre for the sample area

The one commercial multi-storied building in the sample was digitised from the LiDAR data and georeferenced to the 2D cadastre. In this building, individual floors were leased to individual commercial enterprises. Attribute tables were populated with lessees and areas of leased floors. The 3D cadastre for the building is shown in Figure 9.

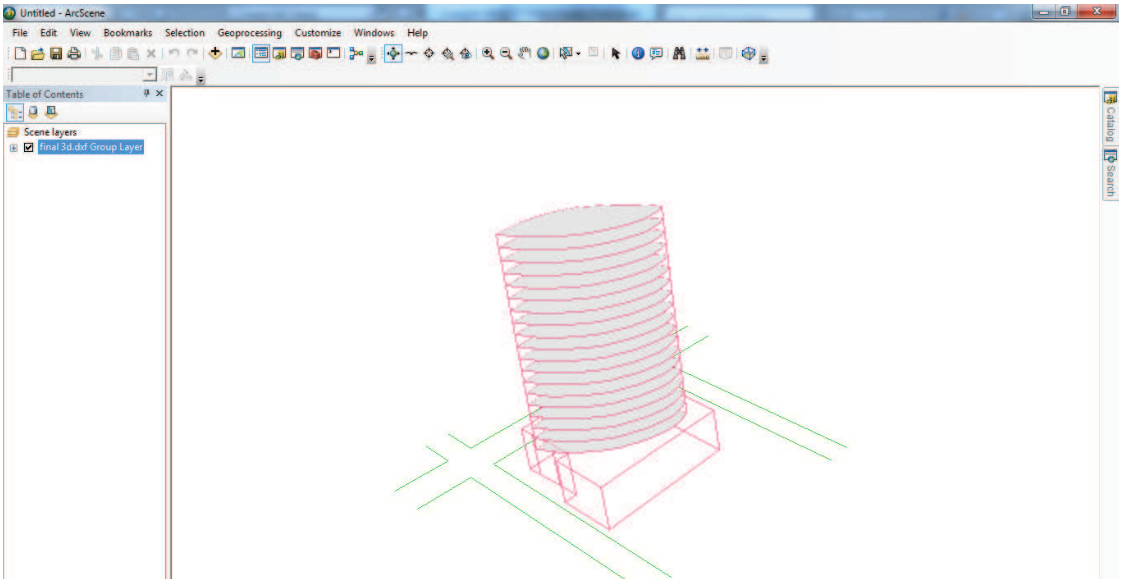

Figure 9. Vectorised data for 3D cadastre in ArcScene

6. DISCUSSION

The boundary system of Trinidad and Tobago is a fixed one where boundary lines are defined by bearings and distances between boundary points that are demarcated on the ground with physical iron markers. These markers only represent but are not the intangible boundary points. In some instances of developed properties, the boundary walls or building walls are placed on the established boundary lines and so are a very good indicator of the location of the boundary lines. In urban areas, where property values are high, the boundary lines are closely reflected by the building walls. General boundaries of stream and river banks and high water lines of the sea, while legally accepted in Trinidad and Tobago are not prevalent in the urban areas so need not be focused on here. Available technologies that can be used for acquiring 3D cadastral boundary data are LiDAR, aerial photography and satellite imagery, and field surveys. The research demonstrated that, in the urban environment, there are instances of properties where, while there are several strata to the buildings, there is one owner or lessee. In these instances the cadastre need not go beyond its current 2D structure.

For 3D apartments and condominium buildings that are individually owned, the cadastral surveyor in Trinidad and Tobago is required to illustrate a cross section on the survey plan that merely identifies the location of the individual parcel in that slice. If the internal locations of the parcel are required to be shown in 3D, the building contractor may be asked to volunteer an as-built CAD drawing that can be imported into the cadastre. The contractor cannot be compelled to do so as the cadastral authorities have no legal jurisdiction to demand it but the building owner may do so in the interests of having their data visible on the cadastre where potential buyers may look. The rules for the performance of cadastral surveys can also be modified to include the requirement for more detailed internal surveys of the strata instead of cross sections only.

The sample site determined that, for Trinidad and Tobago, where the multi storied urban environment is limited in extent and where most of these buildings are solely owned by singular state or private business entities there may not be a need for acquisition of LiDAR data specifically for cadastral purposes unless it is already available for topographic purposes. The 3D cadastre can be developed from digitising of the cadastral plans and extruded upward to the limits of the rights to develop. This limiting upper boundary is not a real estate boundary that describes extents of rights but a planning boundary that describes restrictions to rights.

7. CONCLUSION

Data for the 3D cadastre may be obtained from building plans, field cadastral surveys, and LiDAR scans. Building plans in standard digital formats, especially from as-built surveys that are usually required in construction may be directly input into cadastral software. In many instances, where the entire property, both building and underlying parcel, are owned by one individual, the visualisation of the building is unnecessary. In such instances, the extruded boundaries, raised up to the height of the highest allowable construction, may provide a 3D visualisation of the land rights as well as the planning restrictions. As required by the aim and objectives of this research, the boundary types, the possible methodologies for data capture and the relative need for each methodology were determined. For further research, larger areas of the urban environment may be investigated, encompassing residential condominiums and apartment buildings for feasibility of complete construction of the 3D cadastre.

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BIOGRAPHICAL NOTES

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Dr. Michael Sutherland holds an MSc E. and a Ph.D. in Geomatics Engineering from the University of New Brunswick, Canada specializing in Land Information Management and GIS. He is currently Senior lecturer in Land Management in the Department of Geomatics Engineering and Land Management, and the Deputy Dean (Undergraduate Students Affairs), Faculty of Engineering, University of the West Indies, St. Augustine, Trinidad and Tobago. He is also an adjunct professor in the Department of Geodesy and Geomatics Engineering, University of New Brunswick, Canada. Dr. Sutherland has been a member of the Canadian Institute of Geomatics, and is a member of the Institute of Surveyors of Trinidad and Tobago. He is also an elected member of the Royal Institution of Chartered Surveyors, an Associate of the Canadian Fisheries, Oceans, and Aquaculture Management (C-FOAM) research group, Telfer School of Management, University of Ottawa, Canada, and a Honorary Fellow, Sir Arthur Lewis Institute of Social and Economic Studies, University of the West Indies, St. Augustine, Trinidad and Tobago. Dr. Sutherland was Chair, Commission 4 (Hydrography), International Federation of Surveyors from 2011 until 2014.

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