Review of the Development of 3D Cadastre in Nigeria Using the Land Administration Domain Model Approach

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ABSTRACT

The development of a 3D cadastre in Nigeria using the Land Administration Domain Model approach was embarked on, and the study was based on previous ideas and relevant literature on the subject matter. The land administration system in Nigeria was critically looked into from three perspectives: before, during, and after the colonial era of administration. Previous studies, both within and in other parts of the world, form part of the foundation for the study. The study highlights the possibilities of changing from a 2D to a 3D cadastre and the relevance and advantages of the upgrade. It was mentioned that upgrading from 2D to 3D involves the inclusion of the prismatic volume. Nigeria has undergone various land reform initiatives. The country finds it challenging to implement a single land administration system because of its diverse sociocultural, ethnic, tribal, religious, and linguistic makeup. This study suggested that the government of Nigeria could preserve the rights, obligations, limitations, fundamental characteristics, and features of land administration, registration, and management for the whole nation if the LADM technique was implemented for the 3D cadastre. An essential field of study in environmental science for preserving the built and natural environments necessary for human existence, occupation, and sustainability is the Land Administration Domain Model (LADM). It considers general equity norms and principles, non-marginalization, land acquisition rules, land transactions, and other land-related interests that ought to be connected to the federating units for uniformity. Because it supports a variety of spatial unit types and the ongoing and persistent usage of 3D representatives of spatial units has no influence on the 2D representatives now in use, LADM version C is deemed suitable for adoption. LADM is designed to be globally applicable across many spatial units. Numerous applications of LADM exist, including property valuation, fit-for-purpose land administration, simulating air quality for regional planning, and the study of disaster-prone areas.

Key words: 3D, Cadastre, Land Administration Domain Model, Spatial

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INTRODUCTION

The cadastral administration, registration, and the number of residents on various activities and facilities were all taken into consideration. The cadastre must take into account the third aspect of land administration in order to appropriately manage and proceed with the registration of infrastructure in complicated and developed areas. Definitions of land, cadastre, and land registration were provided by Henssen (1995) and Lemmen (2012). According to his definition, cities are growing as a result of the urbanisation movement, which has raised demand. A cadastre is a methodically organised public database that is based on a survey of a region's

boundaries that contains information about properties within that region. These qualities are methodically recognised using a different identifier. Large-scale maps, along with registers, typically display the boundaries of the property and the parcel number. These maps can also provide information about the nature, size, value, and associated legal rights of individual properties. 3D parcels, which are spatial units having one or more volumes of space, serve as the foundation for a 3D cadastre.

Rajabifard, *et al., (2018)* state that the Land Administration Domain Model (LADM) has been created and approved as an international standard by the International Standardisation Organisation. It was believed that the land administration domain model (LADM) provided an appropriate framework for characterising land-related administrative problems. This approach offers a comprehensive framework for the efficient and successful management of land needed for environmental development and improvement. From a broader angle, it addresses land administration, registration, management, and cadastre. It affects everything of the earth's surface, including the sea, the atmosphere, and the land. It enhances the local, national, and international exchange of land information as well as inter-operational management.

Using Model-Driven Architecture (MDA) to construct an application software or LADM model profile, the Land Administration Domain Model (LADM) provides an official mechanism for assessing land administration data (Rajabifab *et al., 2018).* Planimetric coordinates (X, Y), which are based on two dimensions, are currently used in Nigeria for land registration and surveying purposes. Cadastral items are three-dimensional (3D) in actuality, and their 2D representations cast doubt on their accurate portrayal. The development and implementation of 3D cadastral objects using the Land Administration Domain Model approach requires adjustments and modifications to data collection methods, processing, adjustment, presentation, and processing of survey data in order to achieve a true representation of cadastral objects in 3D.

Environmental issues such as urbanisation, globalisation, sustainable agriculture, sufficient housing, food security, sound governance, etc. have an impact on the design of modern land administration. The principles of the continuum of land rights are the foundation upon which LADM bases its description of land-related issues. It contributes to the aggravating issues surrounding the cadastral realm. Urban regions' expanding population has made land scarcer, which has caused excessive and concentrated property development both above and below the earth's crust. Therefore, it is necessary to view LADM as a significant field of environmental research in order to preserve the built and natural environments for the sustainability and continued survival of humans.

Researchers have made multiple attempts to convert Nigeria's 2D cadastral land administration system to a 3D one. These studies, though, have only been conducted theoretically and have not yet been applied to our country's land administration structure. Thus, the goal of this research project is to create workable routes for the implementation of a 3D cadastre powered by LADM in Nigeria. The study's goal is to use the Land Administration Domain Model (LADM) technique to create a 3D cadastre for Nigeria. The Nigerian cadastre must be upgraded from 2D to 3D in order to accomplish this goal.

AN OVERVIEW OF PREVIOUS RELEVANT STUDIES

The Land Administration Domain Model (LADM) and its associated terminologies are attaining international standards and are the subject of numerous international write-ups. There is a wealth of pertinent literature in this field of study. Babalola, *et al.,* (2017) conducted a preliminary examination of the conformance of LADM for modelling 3D/4D situations. They discovered that most land-related transactions still rely on 2D models, which have slowed down the rapid expansion of densely populated areas. The use of 3D is intended to increase the effectiveness of various models. The development of the land administration platform is significantly influenced by the progress and upgrading of land. They noted that the Land Administration Domain Model (LADM) concept in land administration needed to be improved, and boundaries needed to be created to deal with the existing 2D and 3D, due to the increasing complexity of land use. It is crucial to properly examine and assess the temporal dimension because of the land's extraordinary power. Every LADM package contains temporal (time) components.

 The land administration domain model and its time component were briefly reviewed by Babalola, Rahman, and Tan (2015). The land administration domain model's foundational knowledge was covered in their study. Their study review was based on their acknowledgement of the groundbreaking work done by LADM professionals. The time (temporal) dimension of LADM was highlighted as they examined a few of the published publications from 2006, the year that the standardisation efforts got underway. They came to the

conclusion that in order to accomplish the goal of their study, the technique for the creation and development of the international standard ISO 19152:2012 temporal schema will be used. Workable protocols were suggested by Rajabifard, Agunbiade, and Kalantari (2018) for the use of 3D-NCDB (National Cadastral Data Base). They believed that the procedures for creating the 3D spatial database and updating the current dataset and data gathering techniques to accommodate the 3D digital data were founded on the user needs that were elicited. The effective and practical means of implementing a 3D cadastral system based on LADM in tandem with the existing Malaysian government system's jurisdictional patterns was the main topic of discussion. Using an open-source platform, they started transferring data from a pre-made database to a generic database as well as computer and software programmes and programmes for the use of 3D in cadastral systems and databases.

Shojaei, *et al., (2018)* designed and developed a prototype for a 3D digital cadastre visualisation. In order to facilitate the interpretation of three-dimensional land and property information, they provided a handbook. Their prototype's objective was to illustrate and spread the word about the needs and advantages of a 3D digital cadastre platform. When the 3D model of the multi-story building in Victoria was loaded into the prototype, it revealed the ownership rights of the 12 lots and 2 common properties that make up the building. Several stakeholders were able to view the prototype, and their feedback was taken into account for improvements and future developments. The assessment of the prototype's usability was a significant component of their research's originality and contributed to the advancement of their findings.

In examining the feasibility of implementing the Land Administration Domain Model (LADM) in Nigeria, Babalola, *et al.,* (2015) examined the land administration history of Nigeria, encompassing the pre-colonial, colonial, and post-colonial periods. This provides the study's backdrop. Nigerian land utilisation was divided into five categories: arable land (33%), grazing land (44%), permanent crops 3%), forests and woods 12%), and other 8%. The country's land administration structure was also reviewed. They saw Nigeria's need for land reform as well as the flaws in the Land Use Act.

The development and implementation of the Land Administration Domain Model (LADM) inNigeria's land adm inistration system, they claim, are greatly reliant on land reform. As the national treasury for title and holdings in all regions and cities of the federation, they believed that the legalities surrounding land ownership, rights, restrictions, and responsibilities related to LADM be critically examined. They also recommended that a national data bank be established as well as the development of a platform for land valuation in both developed and undeveloped areas of the nation. For the Land Administration Domain Model (LADM) application for the country profile, they found that the national data bank is a crucial requirement.

In the faculty of built environment and surveying at the University of Malaysia, Babalola (2018) titled his PhD thesis, "Dynamic web for land registration towards the adoption of a land administration domain model in Nigeria." In his introduction, he covered the definition of land, the structure of land administration, and the transition from the core cadastral domain model to the land administration domain model. In his study, he made clear that Nigeria has no established framework or paradigm for managing land. Because of this, it is challenging to create a model or set guidelines for every cadastral procedure. Utilising prior insights from other nations that have embraced the Land Administration Domain Model, he also offered comprehensive suggestions on how to develop sustainable information and communication technology (ICT). Building a web system to improve the current approach, securely monitoring the funding system, and effectively using information and technology to enable the implementation of LADM are all part of his study's objectives (ISO 19152). He noted the problem of corruption in land-related operations as well as the length of time and procedure it takes to obtain a certificate of occupancy (C of O). With the help of PhP My Admin SQL's dynamic web design, a user-friendly platform and dynamic database management system were developed to enable transformation for the LADM specification.

Abolade, *et al., (2018)* used Kaduna State as a case study for their investigation on the difficulties associated with digitising Nigeria's land administration system. They looked at the difficulties that arose from Nigeria's attempt to digitise its land administration system, using Kaduna State as a case study. Several obstacles include inadequate electrical infrastructure, inadequate internet access, inadequate staff training, insufficient funding, and difficulty obtaining necessary equipment, lack of pertinent rules, and database creation and upkeep. Land administration officials and other relevant experts were provided structured questionnaires that were developed based on the identified opportunities and constraints connected to the digitalization of land administration. According to their opinions, one strategy to address some of the issues raised is through employee incentive and

training. The study's sample size is small in relation to the size and population proportion of the nation because it was limited to one northern state. They came to the conclusion that digitization allows for quicker decisions to be made regarding land and also helps to release the cash that is held in untitled landed assets.

Babalola, *et al.,* conducted research in 2017 that resulted in the land administration domain model that is being considered for implementation as a reference model for the land administration system in Nigeria. The system known as LADM, according to this study, enables the ordered and structured presentation of a variety of land-related data from various sources. They began by outlining Nigerian land and land administration. They addressed land administration prior to, during, and following the colonial era as well as LADM packages in order to establish a basis of understanding for LADM implementation in Nigeria. They also completed assessments of the various components of every package and class. They found that the Land Administration and Development Model (LADM) may be widely applied by mapping some of the concepts of the LADM standards into the Nigerian land administration system. Babalola *et al., (2015)* conducted an examination of the 3D situation as a prospect for the land administration domain model (LADM) in Nigeria using an initiative from Malaysia. Because Malaysia's and Nigeria's land administration systems are comparable, this home-based research concentrated on putting the initiative adopted by the Malaysian 3D property situation into practice. They believed that since the research had shown effectiveness in Malaysia, it would likewise likely show similar results in Nigeria. Given this, they proposed using the current cadastral system as a potential model for implementing the Land Administration Domain Model (LADM). The benefits and solutions of the 3D scenario for the Nigerian people and government were also covered. Worldwide development has produced a number of prototypes for presenting 3D digital cadastre concepts. Various national authorities are making efforts to implement LADM internationally and at all levels, albeit conceptual in nature only. As part of its goal inquiry, this study plans to talk about how the existing 2D should be updated to 3D and build a current LADM-driven 3D workflow to support the implementation of the intended LADM-driven 3D land administration systems in Nigeria.

NIGERIAN LAND ADMINISTRATION SYSTEM

The process of ascertaining, documenting, and sharing information regarding the ownership, worth, and usage of land and its related resources is known as land administration. These procedures involve identifying (also referred to as "adjudication") land rights and other characteristics, surveying and characterising them, thoroughly documenting them, and supplying pertinent data to support land markets. Philip Ian Williamson (2000). Many developing, developed, and underdeveloped countries have had multiple births and resurrections of their land administration systems over the years. Nigeria attracted land administration and management systems as well, being a developing nation (Babalola, 2018). Nigeria has implemented various land administration reform projects, each with unique results, ramifications, and adjustments. Nigeria is a diverse nation in a lot of ways. The country's sociocultural, ethnic, tribal, religious, and linguistic diversity made it difficult for it to implement a single system of land administration. Madumere (2019) asserts that before the land nationalisation and unification process that resulted in the Land Use Act of 1978, Nigeria had a few significant and unique land tenure and administrative systems in place. In order of precedence, they were the following: the native customary law-based tenurial rights; the State Land Law-based customary rights; the Received English Law-based customary rights; and the Land Tenure Law-based customary rights. Of the tenancy agreements mentioned above, two were applicable across the country, while the other two followed the North-South divide that was typical of Nigeria (Oshio 1990). Land use is becoming so dense in big metropolitan areas, especially in industrialised countries, that distinct land use systems are being defined. Nigeria is not exempt from these phenomena as a developing country. Due to rural-urban migration, which increased population and concentrated a high concentration of other variables on land, there is an increasing desire and demand for land in Nigeria's emerging cities. The limits imposed on 2D cadastral parcels are represented by the placement of various land use classifications on top of, beneath, and between each other. Examples of current 3D scenarios were provided by Jantien and Martin (2001), including apartment buildings, infrastructure above and below ground, and a rising number of cables and pipes.

METHODOLOGY

The goal of this paper is to examine the appropriate steps taken by the Nigerian government to create a workable, sustainable ideology for the implementation of a 3D cadastre based on the Land Administration Domain Model (LADM), in accordance with Nigerian land registration and administration protocols. It is crucial to investigate how the current 2D National Cadastral System may be converted into a 3D system and to build the workflows and related data needed to adapt the current system to fit into the new 3D system while creating the prototype system for the initiative. The requirements of Nigeria's land management, administration, and registration system documentation must be taken into account in order to accomplish the aforementioned goals. The stakeholder roles and the department's survey and mapping tasks were thoroughly examined and assessed in preparation for the upgrading processing. Experts in land administration and registration were interviewed, internet materials and resources were examined, and process and documentation reviews served as the foundation for the technique that was used.

In order to accomplish the goal of this study, which is to develop a 3D cadastre in Nigeria using the Land Administration Domain Model (LADM) approach, a cadastral database will be created utilising data and information from the Ministry of Lands and Surveys department, working in tandem with the GIS departments run by each state in the federation. They currently run offices at the state ministry levels in a few states in the nation, including Edo, Kogi, and Nasarawa, under the names EDOGIS and KOGIS, where land registrations and matters related to certificates of occupancy are handled digitally. This offers a way to gather data needed to create a LADM. The unique identifier, area and geometry of land parcels, name, ownership number or identity, parcel history, building information model data, and other details are pertinent in this regard. Additionally, a tetrahedral mesh generated using 3D TIN will be utilised to construct the basic cubes that may be used to represent volume parcels for buildings. CAD and GIS tools will also be utilised to present the graphical display. The following other technologies should be used: WebGL, HTML, JavaScript, CSS, and Google Maps. The graphical user interface will be made with HTML and CSS, and visual legal objects and images will be produced using WebGL technology. There are six geopolitical zones in Nigeria. By adopting a state in each zone as a case study and creating a single national model, the study aims to address these zones.

ADOPTED LAND ADMINISTRATION DOMAIN MODEL

The International Organisation for Standardisation (ISO) has released the Land Administration Domain Model (LADM) as a draft international standard under the code ISO 19152 (ISO, 2011c). Lemmen (2012) states that the Draft International Standard has also been submitted to CEN/TC 287. This study work determined that LADM Version C should be used. Because it is divided into three packages and one subpackage, this version was approved. LADM Version C makes it easier for many agencies that operate at the national, regional, or local level to maintain various data sets. Examples of these organisations are land registration and cadastral, each of which has specific duties related to data maintenance.

The core LADM in version C is based on four core classes:

Class LA: Party, parties

Class LA-RRR, rights, restrictions, or responsibilities

Class LA-BA unit, basic administrative unit.

Class LA: spatial units.

The party package, the legal/administrative package, and the spatial unit package are the three packages. To enable application of the LADM at any level, including local, regional, and national, a code listing of the different aspects was incorporated. A wide range of spatial entities can benefit from LADM Version C, which is quite effective. Additionally, it helps to facilitate the development of 3D spatial unit representatives without adding to the workload of currently available 2D representatives. The structured representation between spatial units that are represented in 2D and those that are shown in 3D is a crucial finding about the spatial representation found in LADM. A 2D representation is often seen as a 3D prismatic volume with no upper or lower bound in many different countries. It is possible to unify 2D and 3D representations by using the interpretation (ISO, 2011c, Annex B).
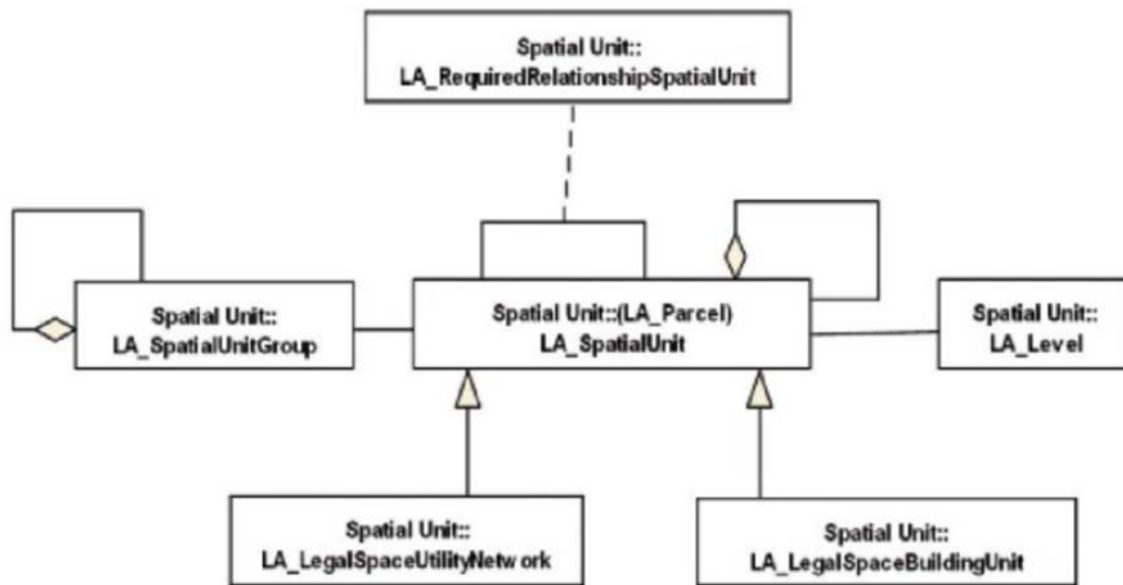
Figure 1: Classes of Spatial Unit Package and associations between them; from ISO 19152

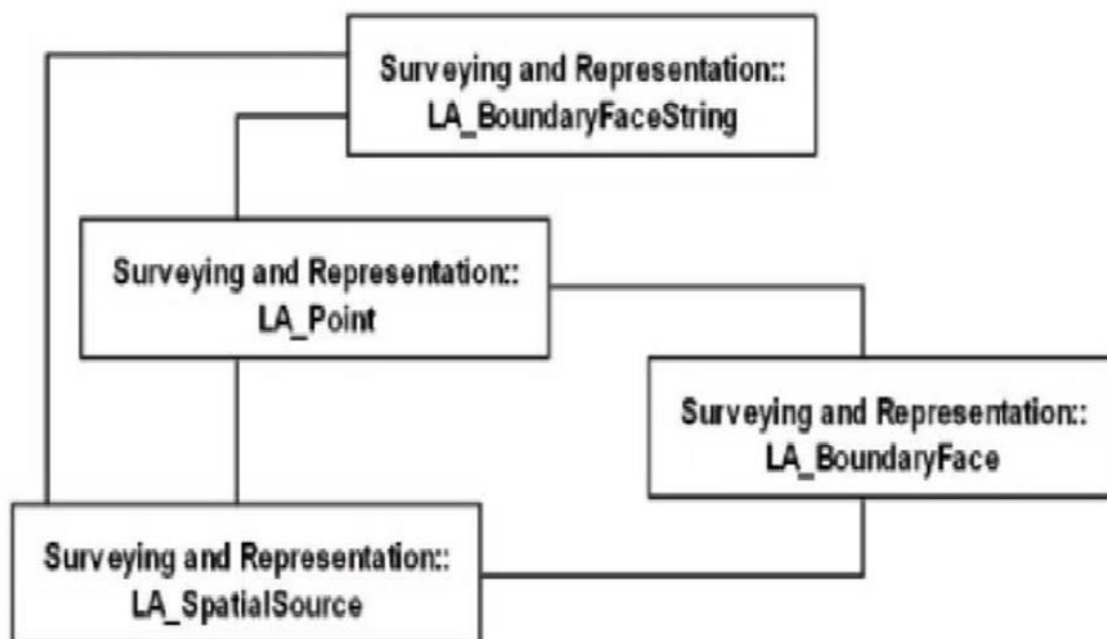Source: (Christaan Lemmen, Rod Thompson and Peter Van Oosterom, 2013)

Figure 2: The LA-Boundary Face String and LA-Boundary classes of the LADM; from ISO 19152.

Source: (Christaan Lemmen, *et al., 2013*).

The LADM has been formalised as an international standard, ISO 19152, after more than ten years of modelling and developing global consensus. Due to its requirement to be globally applicable for a range of spatial units (typical land parcels, legal spaces around buildings, legal spaces surrounding networks and utilities), the LADM provides a relatively generic spatial representation model. Moreover, a range of accuracy levels are provided for text-based, point-based, unstructured (line)-based, polygon-based, and mixed 2D/3D representations.

APPLICATION AREAS OF LAND ADMINISTRATION DOMAIN MODEL

There are numerous applications for the land administration domain model. The goal of LADM is to develop into a flexible instrument for managing and implementing land use on Earth. It was used by Unger, *et al., (2019)*

in their investigation of communities and regions that are vulnerable to disasters. They presented a paradigm that connected the fields of catastrophe risk reduction and land administration. Their objectives were to enhance the ability to withstand natural calamities and offer a method for gathering information once and use it again. A number of Australian studies have used LADM in coastal areas. It was used in the investigation of the frequency of pollutants being recirculated back over the emission location later in the day or even the next day. Physick and Manins (1994) acknowledged this in their study. Another application area is land administration with LADM that is suitable for its intended use. This calls for the usage of GIS and LADM in conjunction with an external GPS device. This method assists in transforming urban areas into habitable environments. This eliminates the need for complicated implementations, specialised skills, or unique programming. Lemmen (2010) states that the model's flexibility allows it to recognise social tenures used by traditional, customary, and tribal people in many countries through the Social Tenure Domain Model, as well as accommodate agricultural land use for the purposes of the European Union's agricultural subsidy.

According to ISO 19152 (2012), LADM is an international standard that offers conceptual and formal language for characterising semantic and spatial information related to RRR that affects buildings, airspaces, and bodies of water or land. According to Rajabifard, *et al., (2018),* LADM aims to achieve two primary objectives. These are intended to provide nations without a modified structured infrastructure system for managing land and property information with a sufficient foundation for an efficient, forward-thinking, and functional land administration system. Additionally, it looks for ways to create a common language so that land administration actors in different jurisdictions or within the same jurisdiction can communicate more effectively. According to Abdul Rahman, *et al., (2012),* 3D cadastre models are helpful for giving existing cadastre systems background assistance. As an accurate depiction of the actual world, they offer the location or spatial details of 3D items. The parties involved are able to comprehend the circumstances and issues surrounding the specific land location thanks to this 3D display of real-world things. It offers ever-more-efficient land-related matter handling.

CONCLUSION AND RECOMMENDATIONS

In order to effectively handle and compete on a global and domestic level in matters pertaining to land administration, registration, and management, Nigeria must create a 3D cadastre utilising the Land Administration Domain Model (LADM) approach. Following the surge in multipurpose cadastre and 3D digital cadastre/database investigations in the early 2000s, the creation of 3D cadastres in Nigeria utilising the Land Administration Domain Model (LADM) approach has become an important field of research. Around the world, a number of models and prototypes have been created. Notwithstanding, our country, Nigeria, still lacks a comprehensive system of 3D land administration that integrates Land Administration and Registration Management (LADM) as a global and national standard. This is because only a small number of researchers have explored this field. Ultimately, Nigeria would be among the nation's leading the way in the adoption of LADM in land administration reforms worldwide if its cadastre system is developed to support the 3D cadastre system. The nation will grow and develop as a result of this development, which will also make the nation socially and economically stable, environmentally sustainable, and allow the government to enact effective and efficient taxation policies.

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