

Missing 'Middle Scenarios': Uncovering Nuanced Conditions in Latin America's Housing Crisis

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Abstract

This article proposes a novel approach to capturing housing deficiencies in rapidly urbanizing regions that is more suitable for data capture, policymaking, and redevelopment. Housing deficit data need to be accurately captured and categorized to adequately act on them. As underscored in the New Urban Agenda, urban policymakers need to be able to set accurate and realizable targets to address the housing crisis. Local governments require precise knowledge of ground realities to strategically allocate money and resources, target solutions, and avoid needless waste. Planners and architects require detailed data and plans to respond to complex conditions. Citizens and nongovernmental organizations should be informed of their communities' needs to engage and collaborate in enhancing local urban service delivery. The goal of this article is threefold: (1) to explore a new method to rapidly capture high-quality housing data in the region; (2) to discuss how these deficits and spatial patterns could be clustered into a new form of place-based deficiency typologies; and (3) to contribute to a more precise analysis of housing shortfalls for planners, policymakers, and local governments using the Latin American region as a case-study scenario.

The proposed solution has the potential to be lower cost, more accurate, rapid, and scalable compared with currently applied techniques and technologies such as census data and satellite imagery. This research serves as a call to action and an exploration in the potential to leverage unmanned aircraft systems and a leading artificial intelligence machine learning algorithm applied to its output data to test, program, and study geospatial data for the purpose of capturing and categorizing rapidly changing qualitative housing typologies in Latin America.

Introduction

Latin America and the Caribbean are plagued by massive housing deficits. Currently, more than 59 million individuals—one in three families—live in deficient housing that lacks basic infrastructure, is unsuitable to inhabit, or built with low-quality materials (Bouillon, 2012). This dilemma is compounded by the fact that Latin America is one of the fastest-growing and most-urbanized developing regions in the world (Bredenoord, van Lindert, and Smets, 2014). Formal housing has not been able to keep pace; illegal or informal settlements have remained one of the more common, and in some regions the primary, means of providing housing for low-income households. In addition, housing occupies the most sizeable surface area in cities. Although figures vary considerably, the principal land use in all cities is residential, occupying from 65 to 75 percent of the surface (Rodrigue, 2013). At the urban scale, tackling the housing challenge directly addresses the most predominant land use in cities. However, deficits in Latin America and the Caribbean are calculated and collapsed into a simplistic binary of qualitative and quantitative shortfalls. An absence of shared definitions, inconsistent methodologies, and outdated information compound this issue. Although directionally helpful, the binary definition of qualitative and quantitative shortfalls is unable to accurately capture complex urban realities. Binary definitions are static and do not help pinpoint acute needs. Moreover, binary definitions do not measure the magnitude of specific characteristics of the housing crisis at a neighborhood, urban, or regional scale. Categorizing housing deficiencies through a binary lens helps produce binary responses. Nuanced and targeted solutions that address ground realities are likely neglected.

Among the main pillars examined and problematized at the 2016 United Nations Conference on Housing and Sustainable Urban Development (Habitat III) were guidelines and improvements to national urban policy and housing policies (clustered under the key areas of urban frameworks, and urban housing and basic services respectfully). Habitat III also addressed the need for accurate and timely data capture to ensure closer alignment between local needs and national urban planning frameworks. As stated in Habitat III's *New Urban Agenda*, articles 111 and 156 affirm the importance of capturing “differentiated analysis of housing supply ... based on high-quality, timely, and reliable disaggregated data at the national, sub-national, and local levels” and encourage the use of digital tools such as “geospatial information systems ... to improve long-term integrated urban and territorial planning and design” (United Nations, 2017).

Drivers for Change: Why Is a New Approach Needed?

The current method used to define and analyze the housing deficit in Latin America is binary and, therefore, limited. The housing shortage in Latin America is neither a monolithic statistic nor binary in nature. Regional housing deficits are calculated and collapsed into a simplistic binary of qualitative and quantitative shortfalls. Qualitative shortfalls represent the inadequacy of housing units with respect to structural shortfalls, such as poor housing materials and quality; insufficient space; privation of basic infrastructure (for example, electricity, sanitary disposal of waste, and potable water); poor location; and insecure tenure. Quantitative deficiencies denote a lack of shelter, severe overcrowding, or a need for a completely new dwelling. Although directionally helpful, the binary definition is unable to accurately capture complex urban realities. The definitions are static

and do not pinpoint acute needs, nor do they measure the magnitude of specific characteristics of the housing crisis at the neighborhood, urban, or regional scale. Examining and categorizing housing deficiency through a binary lens helps produce binary responses. Nuanced, targeted, and effective solutions that address the ground reality likely are overlooked or neglected. As underscored throughout the *New Urban Agenda*, the development of robust and accurate urban policies is vital to providing the necessary framework and support to urban development, acting as a key instrument to capture and target current and future urban priorities and to coordinate and guide the actions of national and local actors, as well as private and public investments.

Housing deficiencies do not exist in a binary bubble. The urban reality is much more complex, with a wide variety of conditions that constitute “middle scenarios.” This article argues that these missing middle scenarios—which cut across regional, urban, and neighborhood scales—need to be explored and exposed. Imagine an agglomeration of poorly ventilated slum housing in an urban center with weak roofs and collapsing walls surrounded by highrise buildings. Compare this scenario with decrepit lowrise social housing in a periurban region rebuilt with deteriorating walls and roofs and with little to no access to public transportation or schools. Although both display similar measures of qualitative shortfalls (for example, weak walls and roofs), these two scenarios have very different sets of conditions and solutions. An analysis of housing shortfalls more suitable for redevelopment is desperately needed.

To generate accurate policies, urban plans, and architectural or landscape designs, middle scenario typologies are needed to reflect the complexity of the housing challenge and condition. Although a significant range of complex urban conditions exists, patterns of typologies likely will emerge. These patterns need to be captured, learned, and analyzed. This article explores a solution to this challenge; it proposes that a catalog of local, regional, and national housing deficiency typologies be developed through pattern-recognition and machine learning on the back end of an unmanned aerial vehicle (UAV). The goal of cataloging these deficits is to generate a new method of clustering typologies and a more nuanced analysis of the housing deficit. In sum, the proposed solution would help address the shortcoming of current measurements and provide a novel approach to collect and parse housing deficiency data.

Institutional Challenges

In Latin America, an absence of shared definitions and a prevalence of inconsistent methodologies and outdated information characterize the quantitative and qualitative shortfalls regarding housing data. Little agreement exists in the region as to what defines qualitative deficiencies and adequate shelter or as to the methodology of how to capture these shortfalls. Definitions vary by country and by researcher in the field of housing, from setting a minimum predefined livable space—wherein households or individuals living beneath this minimum requirement are classified as inadequate—to assessing housing conditions by measuring levels of deprivation (Rojas, 2015).

There is a paucity of data. The Economic Commission for Latin America and the Caribbean completed the most recent Latin American regional assessment in 2000, primarily by drawing on census data from the 1990s (UN-Habitat, 2011). Census data largely exclude informal areas and settlements. Ad hoc or independent efforts have been launched to address this data gap by the

Center for Social Research at the nonprofit TECHO or through an interim housing census launched in 2015 in Brazil and Mexico (to be carried out every decade).¹ Nevertheless, there remains a lack of timely, high-quality data capture and analysis. Specifically, local and national data on informal settlements tend to be imprecise and fragmented (Fernandes, 2011). Moreover, despite the fact that numerous regional and international agencies attempt to provide reliable statistics and encourage standardization and updated methodologies to measure deficiencies, a desperate need remains for the production of standardized and periodic data.² Census data are captured every decade. Regionally, the average amount of time dating to the most recent census is more than 6 1/2 years (see exhibit 1). Outdated, inaccurate, and binary information needs to be replaced, and the absence of shared definitions and inconsistent methodologies needs to be countered.

Exhibit 1

Census Data Captured by Year, Latin America



Notes: At the time of this research, Guatemala’s Instituto Nacional de Estadística (INE) website was disabled and not open to the public. All countries that conduct the housing census collect qualitative and quantitative housing data. In 2015, Mexico and Brazil introduced an interim housing census that will be carried out every decade. Chile will create a new one-off census in 2017 because the data captured in 2012 did not adhere to the required data standards.

Sources: Map by Kira Intrator and Ricardo Martínez Campos using data from Instituto Nacional de Estadística y Censos (INEC; Argentina); Instituto Nacional de Estadística de Bolivia (Bolivia); Instituto Brasileiro de Geografia e Estatística (Brazil); Instituto Nacional de Estadística (INE; Chile); Departamento Administrativo Nacional de Estadística (Colombia); INEC (Costa Rica); Oficina Nacional de Estadística (Dominican Republic); INEC (Ecuador); Dirección General de Estadística y Censos (El Salvador); INE (Guatemala); INE (Honduras); Instituto Nacional de Geografía, Estadística e Informática (Mexico); INEC (Nicaragua); INEC (Panama); Dirección General de Estadísticas, Encuestas y Censos (Paraguay); Instituto Nacional de Estadística e Informática (Peru); INE (Uruguay); INE (Venezuela)

¹ To counter the lack of data on informal settlements, the Center for Social Research conducted alternative census studies in Argentina, Chile, Colombia, and Nicaragua in 2015.

² Examples of regional and international agencies seeking standardized definitions, updated housing indicators, methodologies, and regional coordination around indicators include the Regional Office on Latin America and the Caribbean, the Latin American and Caribbean Demographic Centre, and the Global Housing Policy Indicators.

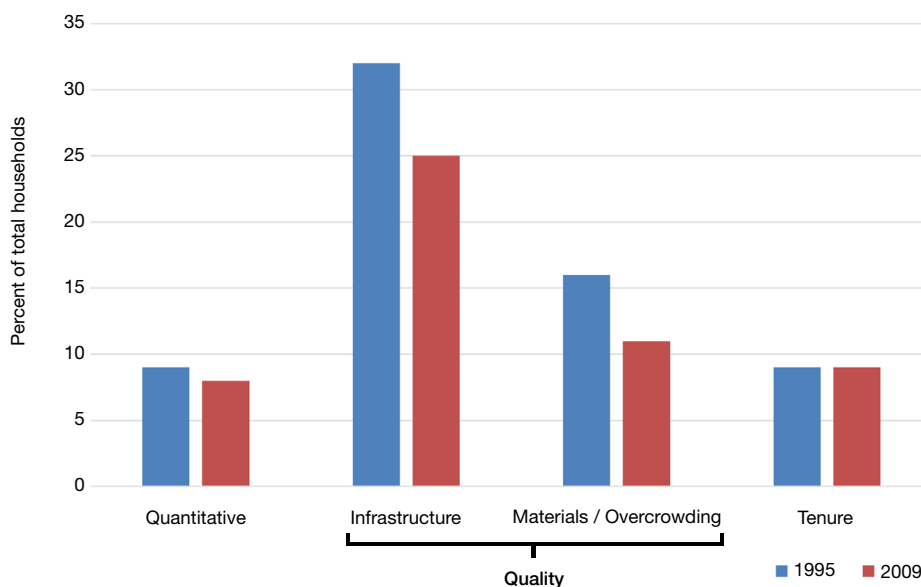
General Scope and Scale of Challenge

The regional, urban, and neighborhood-scale impact of Latin America's housing crisis is massive. Latin America's housing deficit and the concomitant rise of central and peripheral informal housing settlements has heightened large-scale urbanism challenges. The dynamics that determine polycentric or periurban expansion are complex—ranging from housing policies, sociospatial issues, a lack of serviceable land, and weak urban planning and infrastructure—a chief result of which is the unavailability of suitable, affordable housing.

Urban areas in Latin America suffer primarily from qualitative housing deficiencies. Of these qualitative deficiencies, the most pervasive is inadequate infrastructure, followed by a shortfall in the quality of the materials used for shelter. Basic infrastructure provision includes sanitary disposal of waste and access to electricity and potable water. Additional qualitative shortfalls include overcrowding; poor-quality or impermanent materials; inadequate roof, wall, or floor conditions; and tenure. Rojas and Medellín (2011) corroborated that the region's greatest unmet need is qualitative (exhibit 2). In addition, statistics published at a major continental ministerial meeting indicate that 60 percent of households have access to suitable housing in the region. Of the remaining 40 percent, 22 percent live in dwellings that are structurally deficient and the final 18 percent need entirely new houses (MINURVI, 2007). According to more recent studies in the category of infrastructure, the leading challenge is inadequate sanitation, affecting 13 percent of urban households (about 17 million households), and 6 percent (or 8 million households) lack piped water. Electricity access appears to be inconsequential, with nearly universal coverage (Bouillon, 2012).

Exhibit 2

Urban Housing Deficiencies by Type, Latin America



Source: Adapted from Rojas and Medellín (2011)

Uncovering 'Missing Middle' Scenarios in Latin America's Housing Crisis

A UAV, commonly known as a drone, is a pilotless aircraft. UAVs are a component of unmanned aircraft systems (UAS), which include a UAV, a ground-based controller, and a system of communications between the two. The flight of UAVs may operate with various degrees of autonomy, either remotely by a human operator or fully or intermittently autonomously by onboard computers (ICAO, 2011). UAS provide a cheaper and faster alternative to conventional mapping techniques. The advantage of using these systems is demonstrated in the speed and accuracy with which they provide geospatial data and their capacity to generate accurate data of existing formal or informal spatial developments. UAS are a logical means of collecting and parsing spatial patterns and data due to the fast pace of Latin America's urban growth, the presence of undocumented informal housing settlements, and the fact that housing census data are collected once every decade. The proposed solution is for the UAS data to feed into a new form of image-based machine learning, developed from current urban conditions. Machine learning, using the long short-term memory (LSTM) algorithm, would help surface patterns and provide the primary input to the formulation of these missing middle scenarios and urban spatial typologies.

UAS counter the cost, complexity, and time of conventional mapping. Multilateral agencies, researchers, the private sector, and governments are testing the nascent field of UAS mapping. During the past year, for example, The World Bank used UAS to generate geospatial data for surveying land in countries with weak or outdated geospatial data infrastructure (World Bank, 2016). At a smaller scale, independent research initiatives experiment with UAS as a primary input for participatory mapping and to collect geospatial data for informal housing settlements in unmapped regions (Barnes, Volkman, and Muller, 2015). Through seed funding from initiatives such as Drones for Good from the United Arab Emirates, private-sector startups use UAS to undertake a range of activities such as three-dimensional mapping, ocean navigation and surveillance, and emergency surveillance in remote geographies (UAE Drones for Good, 2017).

In Latin America, governments primarily use UAS for activities related to intelligence, surveillance, and reconnaissance operations, with a few governments beginning to apply alternative purposes such as monitoring environmental crimes in the Brazilian Amazon rainforest and architectural digs in Peru (Cawley, 2014, 2013; Emol, 2013). However, these data collection approaches remain binary in nature and do not employ or combine artificial intelligence with UAS. The proposed approach and solution has yet to be applied to defining or addressing the housing crisis in developing regions.

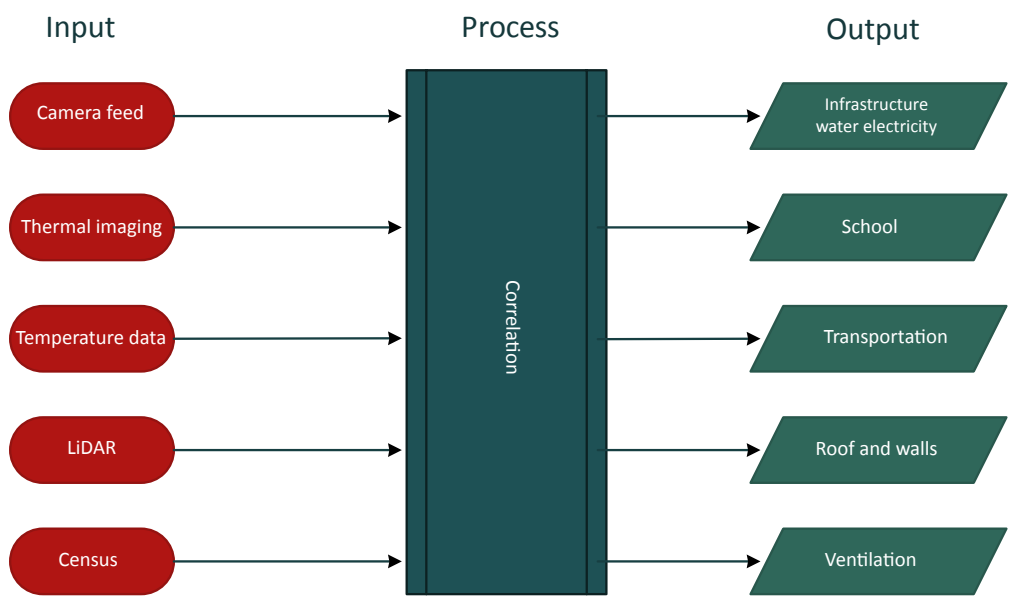
The UAS could be used in a new way—to test, program, and study geospatial data for the purpose of capturing and categorizing qualitative housing typologies in Latin America. UAS have yet to be deployed in Latin America for the specific use of cataloging housing and their surrounding urban spatial characteristics. This idea responds to a critical need for urban and housing deficit data that are accurate and rapidly generated. The proposed solution could use and expand on current data libraries as a baseline input (for example, census data, local survey data, infrastructure provision,

and so on) related to qualitative urban housing conditions. Moreover, the solution aims to capture the types of shortages compromising an individual home, as well as examine the larger urban fabric in which it resides.

The proposed concept explores a novel approach to the data mining process by using the latest LSTM model. Predictive models, such as deep neural networks, have the potential to generate a real-time heat map of city characteristics and housing deficiency needs. Many of the recurrent neural network algorithms, such as the LSTM model that contains prolific nodes, have made an impact in real-life applications. LSTM is extensively used and adapted through algorithms involving speech recognition and are applied in the field of robotics for vision analysis, scene labeling, and face recognition. For example, in their work of speech recognition, Sak, Senior, and Beaufays (2014) dissected acoustic frames that were analyzed using a phoneme database with the LSTM model. Unlike the simple feed-forward neural networks, LSTM models are tantamount to cyclic connection-based modeling sequences; through the use of LSTM, these sequences are converged quickly, and the data are processed in real time. The proposed model is unique because of the parameters that are input into the algorithm. Although a simple LSTM network, this model will be peculiar in that the data provided by the drone will be processed in real time using its array of various sensors (see exhibits 3 and 4).

Exhibit 3

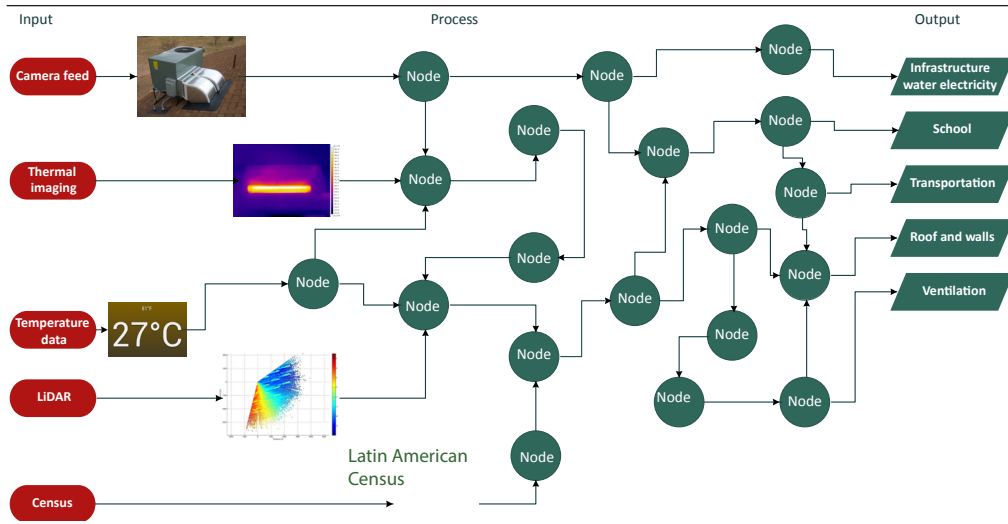
Input and Output Samples for the Long Short-Term Memory Algorithm



LiDAR = Light Detection and Ranging.

Exhibit 4

Snapshot of Long Short-Term Memory Algorithm (or Reoccurring Neural Network) Functions



LIDAR = Light Detection and Ranging.

Implementing the Model

LSTM models are well known for finding both closely related and sparsely related dependencies. This important characteristic of LSTM models can be directly correlated to our problem statement. The short-term dependencies will develop logic nodes for medium-sized databases with immediate connection to the output—for example, connecting light detection and ranging (LIDAR) data to calculate the distance between objects and gather information on the number of floors of a building. In contrast, the long-term dependencies of the model will be capable of relating abstract concepts to one another.³

The input to the proposed solution includes UAS equipped with camera feed, thermal imaging, and LIDAR sensors (exhibit 3). Existing census and temperature data would further be fed into the LSTM system as external data sources. The camera feed from the UAS is of higher quality, more detailed, less expensive, and more timely than census data collection and has the potential to be much more scalable than existing satellite or Landsat imagery. Thermal imaging enables estimates of how many people live in a given house or area, and LIDAR would provide basic input such as the topography of the region and the height of buildings (for example, LIDAR combined with thermal imaging data could be cross-referenced to calculate how many individuals live in a given dwelling and space).

³ For example, a long-term dependency could include connecting temperature data from a region with the availability of public transportation. Even though a heat map of a particular area may seem superfluous in identifying the availability of public transportation, such data help determine the relationship by linking the heat map data to previous data samples. If a similar pattern of heat map variations with respect to time were found after the introduction of public transport in another region, the algorithm would conclude the presence of public transport in an area with similar heat-map-to-time data patterns.

A prototype of the LSTM model could be conducted in a small preselected urban agglomeration in which input parameters are collected and the LSTM model trained through data tagging of the region. In its maiden flight, the drone gathers data and streams it to a local database. The LSTM model would use this data to correlate and drive conclusions about the spatial patterns and clusters of housing deficiencies of that area. Previous census data would then be compared with these findings and the aberrations used to fine-tune the LSTM model. Once such a network is established, it would use the correlation (also known as learned neural network nodes) on the surrounding houses in the area (see exhibit 4). The UAS, when deployed, will transmit massive amounts of data to online servers for large-scale computations. An important feature of the LSTM model is the ability to process data in real time. The model is capable of processing gathered intelligence and correlating it with previous data, thus providing output in real time. Real-time output makes the data processing faster. The algorithm would be deployed on rented servers, as the server environment would enable easy and, in most cases, automatic expansion of the algorithm through the self-replication of the code. This ability to extrapolate its computational capability would not only enable multiple drone deployments but would keep the downtime of the model to a minimum, due to the fact that servers have multiple redundancies. Such a model of running algorithms on low-cost, dedicated rental servers is advantageous, as it would allow for building on the readily available high-tech infrastructure of premium server services such as Amazon Web Services and Google Cloud Platform. With respect to the financials of deploying the UAS, the initial hardware costs incurred for the drone, LIDAR sensors, and thermal imagers would be substantial. After this initial investment, longer-term recurring charges would be minimal and include only hardware maintenance and server infrastructure charges. Moreover, the pool of big data that this type of initiative would generate would be massively helpful to multiple sectors across industries. For example, the real estate industry would be able to locate regions requiring redevelopment, the food and supply industries would be able to better allocate resources, and governments would be able to map and create requisite policies to abate high levels of pollution.

To generate correlations and categorize spatial housing deficiency patterns, the algorithm receives data from the UAS. The algorithm will initially generate nodes, or so-called virtual decisionmakers, and start interconnecting the nodes based on the type of data collected in real time from the drone. This interconnection of nodes will enable users to conclude connections and map out high-quality housing deficiency patterns through the use of remotely related parameters. For example, UAS send data of a select region to the servers. The algorithm uses the primary data from the camera feed to process telltale signs that certain objects are present on roofs by comparing them with its database of objects. For example, the UAS discovers the existence of large ventilation shafts and air-conditioning units on a roof, and the algorithm concludes that the building is well-ventilated. Object recognition and image annotation will be carried out by matching object features, including speeded-up robust features (SURF) and Fast Retina Keypoint (FREAK) features. The SURF and FREAK features enable the LSTM algorithms to match corner points and edges of objects in the camera feed. This feature comparison makes it possible for the model to detect ventilation, the availability of water supply by detecting water pipes, and structural integrity of the buildings through the detection of crevices in buildings and discoloration of walls. Other data, such as the LIDAR sensor feeds, enable a topographical analysis of the region and a calculation of the height of given infrastructure and buildings. Another critical feature of the neural network is its ability

to predict certain outputs in the absence of direct inputs; it extrapolates the data it has retrieved to predict parameters it has never been fed. It does so by extrapolating from indirect inputs. For example, if no image or sensor data of the interiors of houses exist to provide direct information regarding levels of overcrowding or the quality of floors or ceilings, it uses thermal images and LIDAR data to relate them to floor and ceiling conditions. Although the accuracy of the model reduces when relying on indirect parameters, it is an added advantage nevertheless.

A limitation of the proposed model is that the sensors used by the UAS are susceptible to weather changes. One way to tackle this issue is by adding or subtracting Delta errors to the sensor readings. However, this adjustment would eliminate the error only if these weather-induced errors remained constant when data are fed to the network. In contrast, weather induced errors fluctuate considerably when covering a large area. This limitation would be addressed as the network grows; with a substantial amount of data, the error is reduced by taking the simple average of repetitive data. An additional implementation challenge to be addressed would be military areas and no-fly zones. To address this issue, the data channeled through the network could be preprocessed to avoid legal and privacy issues. Such an attempt can be made by selectively muting onboard sensors when a drone flies in those areas. Many Latin American countries have their own drone regulations. Panama, for example, divides drones into four categories based on weight (AAC, 2016). Argentina requires drones to stay out of a 5-kilometer radius around airports (ANAC, 2015).

Conclusion

Housing deficit data need to be captured and categorized accurately for policymakers, urban planners, architects, citizens, and nongovernmental organizations to adequately act on it. This article outlined a novel approach to capturing and recategorizing missing middle scenarios of rapidly changing qualitative housing typologies in Latin America by leveraging UAVs and neural network machine learning. The proposed solution is more suitable for data capture, policymaking, and redevelopment in rapidly urbanizing regions and has the potential to be lower cost, more accurate, rapid, and scalable compared with currently applied techniques and technologies such as census data and satellite imagery.

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