Dwelling stock dynamics for addressing housing deficit

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A B S T R A C T
Housing in developing countries is often inadequate due to overcrowding, lack of suitable shelter, lack of sanitation and exposure to natural hazards. The United Nations classifies these conditions into two types of deficit: quantitative and qualitative. Strategies for eliminating housing deficits need to consider the dynamics of the total dwelling stock in order to balance this objective with other goals, such as employment in the construction sector, costs, and environmental impacts. Existing dwelling stock models were developed mainly for developed countries and are not suitable to address housing deficits. Here we use a case study for Colombia’s housing stock to propose a dynamic stock model that incorporates deficit. We analyze the evolution of the stock under twelve scenarios combining three projections for household growth and four trajectories for eliminating deficit. The model is calibrated using census data, UN population projections, and own appraisals of household size, based on historical trends. Our results show that closing all deficits by 2030 would require upgrading 2.8 to 3.3 million existing dwellings and building 3.6 to 6.3 million new dwellings, depending on demographics. This represents an increase of 97–155% in construction activity. Conversely, if deficit stays at the current 31% level, 5.1 to 7.9 million households would be in deficit by 2030.

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1. Introduction

1.1. Housing deficit in the developing world and Colombia

Most developing countries exhibit higher rates of population growth than developed countries, and have experienced rapid urbanization (Cohen, 2004). In many parts of the world, this growth has been decoupled from economic growth (Cohen, 2004) which has resulted on growing informal settlements, and large numbers of households with unsatisfied housing needs (UN-Habitat, 2003).

In 2012 UN-Habitat (2012a) estimated that 863 million people lived in slums; corresponding to 32.7% of the urban population in developing regions. The largest shares of slum population appear in Sub-Saharan Africa (65%), Southern Asia (45%), South Eastern Asia (39%), and Eastern Asia (37.4%), followed by Latin American and the Caribbean (29%) (Statista, 2016; UN-Habitat, 2012a; UNSD, 2015). For the latter region, the Inter-American Development Bank estimated that 37% of households in 2009 had unsatisfied housing needs (Bouillon et al., 2012b). Low household income, labor informality, high interest rates, and high cost of land and materials are some of the barriers that prevent access to formal housing (Bouillon et al., 2012a) and explain the prevalence of inadequate housing in developing countries.

Colombia is a case representative of the housing conditions observed in other developing nations. First, fast urbanization, sustained population and economic growth, and high inequality (Ortiz and Cummins, 2011; World Bank, 2016) have created housing needs that are inappropriately satisfied because there are considerable access barriers, particularly to land and financing (Bouillon et al., 2012b). Second, ownership is preferred over renting because investing in housing is perceived as a way to save and create family wealth (Gilbert, 2001). Nonetheless, income inequality in Colombia is among the highest in Latin America and the world (World Bank, 2016), and most of the population has no access to housing credit (Murcia Pabón, 2007). Housing policies that promote financing rules and increase access to credit through demand subsidies and interest rate subsidies (Fique Pinto, 2008), have limited impact because 47% of labor is informal (Dane, 2016).

Like many developing nations, Colombia has had a long-term historical mismatch between demographic growth and housing availability. Colombia is the third most populated country in South America with an estimated population of 48.2 million by 2015 (United Nations, 2015). Between 1950 and 2005 the Colombian
population increased twofold, at declining growth rates. Following a trend observed in developed and other Latin American countries, household size decreased from 5.8 to 3.9 persons per household between 1950 and 2005 (United Nations, 1974; DANE, 2005). While population growth and household size decline caused total households in 2005 to increase by a 3.7 factor with respect to 1950, the dwelling stock growth lagged behind, increasing unsatisfied housing needs (DANE, 2005).

For policy and accounting purposes, unsatisfied housing needs are referred to and measured as “housing deficit”. Housing deficit is measured as number of households. Households are defined as arrangements of one or more persons who “make common provision for food or other essentials for living” (United Nations, 2014). Qualitative deficit accounts for dwellings with deficient conditions (materials, space, and basic services) that can be improved, and quantitative deficit refers to dwellings with non-remediable overcrowding and structural deficiencies (DANE, 2008). As these definitions are ambiguous and deficit measures rely on normative assessments of quality and overcrowding, deficit estimations are subject to high uncertainty (Monkkonen, 2013). Colombia’s latest census in 2005 reported housing deficit at 36% expressed as 12% quantitative and 24% qualitative (DANE, 2005). Although housing deficit decreased 1.5 points per year between 1993 and 2005, during the same period, the number of households with deficits remained practically unchanged, with a 0.34% decrease (CENAC, n.d.). These figures show that housing policies in Colombia have failed at attending population with housing deficits.

Housing policies in Colombia have followed a similar path as those in other Latin American countries (Boullon et al., 2012b; Murray and Clapham, 2015), evolving from financial mechanisms created in the 1950s to interest rate subsidies and cash transfers 1950-date. Historically, these policies have especially increased housing provision for middle-income households (Gilbert, 2014), but have failed to cover households below the national poverty line, which account for 78% of housing deficit (ONU-Habitat, 2012). In 2012 a radically different policy of building 100 thousand free dwellings for poor households was adopted (Congreso de Colombia, 2012).

1.2. Modelling dwelling stock dynamics and housing needs

Understanding the state, composition and dynamics of dwelling stocks is necessary to evaluate the impact that strategies for closing deficits have on construction materials consumption and demolition waste management, among other factors. The importance of dwelling stock dynamics has been extensively discussed in the literature in the light of: (i) socioeconomic and quality of life concerns, (ii) climate change and energy use, (iii) material use and resource efficiency, and (iv) construction, demolition, renovation and land use planning (Kohler and Hassler, 2002; Lucon et al., 2014; ONU-Habitat, 2015; Schiller, 2007; Seto et al., 2014; UN-Habitat, 2012b, 2003; Ürge-Vorsatz et al., 2012).

Correspondingly, a variety of approaches has been proposed and used for building stocks’ research as reviewed by Swan and Ugursal (Swan and Ugursal, 2009) and Kavgic et al. (2010). Vásquez et al. (2016) also presented a detailed review of studies on the topic, and found that most comprehensive studies for the investigation of the building stocks’ long-term dynamics and externalities employ a stock-driven approach. Stock-driven models, common in the Material Flow Analysis (MFA) field, have supported the study of construction, demolition, renovation, and material and energy use in developed and developing countries (Bergsdal et al., 2007; Gallardo et al., 2014; Hu et al., 2010a, 2010b, 2010c; Müller, 2006; Pauliuk et al., 2013; Sandberg et al., 2011, 2014a, 2014b; Sandberg and Brattebø, 2012; Sartori et al., 2009, 2008; Vásquez et al., 2016).

Developed and developing countries have similar problems with planning and resources use, which justifies the use of the same modeling approaches. However, the economic and social conditions of developing countries pose unique challenges for modeling building stocks. In particular, current MFA models are not designed for addressing issues related to large and growing populations living in substandard dwellings. Only four studies that use stock-driven models for developing countries were found: three cases on China (Hu et al., 2010a,b; Huang et al., 2013), one that differentiates urban and rural dynamics and two that focus on materials; and a fourth case on Chile (Gallardo et al., 2014) that incorporates earthquake vulnerability and damage.

MFA models that represent the conditions of developing countries can contribute to the formulation and evaluation of housing policies that address problems particular to these countries. In this paper we develop a stock driven model that estimates the construction and renovation activity needed to close quantitative and qualitative deficits under different socio-demographic scenarios and at different time horizons. This is a first step for estimating the materials and resources needed to satisfy future housing needs in developing countries with housing deficiencies. We apply the model to the case of Colombia, which is representative of upper-middle income developing countries.

2. Method

2.1. System definition

Fig. 1 describes the system and depicts the stocks and flows of households and dwellings. Both stocks are differentiated by three types of housing deficit conditions: No Deficit (ND), Qualitative Deficit (QL), and Quantitative Deficit (QN), according to the UN definitions (ONU-Habitat, 2015).

Two kinds of household flows are distinguished. First, inflows or outflows to the stock, driven by sociodemographic growth, which are internalized in the stock change of each type. And second, internal flows between types. The latter are two unidirectional flows from qualitative (QL) and quantitative (QN) to no (ND) deficit. The system is defined for the evaluation of policies that aim at closing the deficit gap, thus deterioration of household conditions is not studied.

Three kinds of dwelling flows are studied: constructions, demolitions, and upgrades. Constructions and demolitions represent inflows and outflows to and from the stock, respectively. Demolitions include those dwellings reaching the end of their service life plus the vacant dwellings with non-remediable deficiencies (QN), which are assumed to be always demolished because they are (i) inadequate for housing and (ii) built with flimsy materials. Upgrades is a unidirectional flow that only applies to qualitative-deficit (QL) dwellings entering the no deficit (ND) stock. This change of type implies refurbishment or remodeling of the dwellings.

2.2. Model description

A dynamic type-cohort-time model was developed for this study. It combines the stock-driven and the activity-driven approaches in standard MFA methods, and it makes use of a discrete difference-equations system. It builds on the modeling principles for residential building stocks introduced by Müller (2006) and discussed and extended by Vásquez et al. (2016). A 251-year time frame (1850–2100) is defined to allow for the accumulation of gradual changes in dwelling stock size and distributions of type and age. These changes are caused by slow changes in demographics and lifestyle, and by the long lifetime of buildings. By modeling a stock with a closer resemblance with reality, we enhance the applicabil-
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