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Urban floorspace distribution and development prediction based on floorspace development model

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ABSTRACT

Floorspace spatial development is indisputably the most essential indicator to reflect the spatial distribution of activities especially in mega cities. To forecast the housing floorspace distribution, a three-step Floorspace Development Model (FDM) is developed in this study based on indicators of permissible development constrains, floorspace areas, and house rents. Beijing is selected as the case study area in consideration of its high house price and limited space. Since government plays a key role in the estate development in China, the housing floorspace is estimated through three steps including unconstrained floorspace estimation, constrained floorspace estimation, and zonal floorspace allocation. This FDM model is applicable to forecast the developers' decisions based on market rules and government policies, which combines China's special conditions with prediction method perfectly for the first time. Based on this model, floorspace distribution and development prediction can be achieved, laying a solid foundation for assessments of servicing, industrial and educational floorspace development and distribution at urban scale especially mega cities in China.

1. Introduction

Urban floorspace provides space for urban activities, which makes it a key role in determining the location of activities, including where to live, where to work, and where to shop. Generally, urban activities interact with each other, and the spatial patterns of urban activities change over time. Given the obvious links between real estates and urban activities, floorspace spatial distribution is indisputably the most essential indicator to measure the spatial distribution of activities (Simmonds, 1999; Wegener, 1999).

Since 1960s, tremendous work has been conducted in the aspects including urban land use, transport and interactions. Alonso (1964) analyzed the land value and its relationship with transport based on neo-classical demand and substitution theory. Wingo (1967) found a negative correlation between land value and transportation costs, i.e., the land value decreased along with a non-linear increase of transportation costs. Kain (1962) related the land value to population location and justified the decay of population densities from employment centers with the existence of multiple socio-economic groups. Clark (1967) observed that the exponential decay in population densities from town center was valid, but the effects of housing floorspace distribution did not receive due attention. Peiser (2015) studied the factors which affected estate development systematically. Echenique, Crowther, and Lindsay (1969) established the relationship between floorspace ratio (i.e., quantity of floorspace per unit of land) and the accessibility to employment centers, and developed a stock model to forecast the floorspace distribution changes, which had been adopted by some Land-use/Transport Interaction (LUTI) models (Echenique, 2011; Echenique, Hargreaves, Mitchell, & Namdeo, 2012).

Besides, floorspace demands and house rents have attracted considerable amounts of research since the middle 1980s (Corcoran, 1987; Hendershott & Kane, 1995). Rosen (1984) laid out the basic supply and demand equations. Survey work has attempted to identify the key criteria used by occupiers to select space (Markheath, 1992), to examine the determinants of the decision to relocate (Markheath, 1992; Willman, 1992), and to assess current and future space requirements (Ellis, 1994). Further research investigated the management of corporate real estate, at a strategic level and in relation to daily decisions, for example the occupational density (Eve, 1997). Hendershott, Lizieri, and Matysiak (1999) proposed a model to forecast rents based on vacancy rates, demand and supply for floorspace and to forecast the completion of office floorspace based on the vacancy rate and rent.

All these abovementioned studies contributed significantly to the urban development and house rent analyses. However, most of the

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studies were conducted in consideration of foreign situations. As for China, most research focused on urban expansion, population growth (Gao, Wei, Chen, & Chen, 2014; Liao & Wei, 2014; Liu, He, Zhang, Huang, & Yang, 2012; Long, Han, Lai, & Mao, 2013), estate prices (Dong, Zhang, Wu, & Guo, 2011; Niu, Liu, & Feng, 2016) and other peripheral aspects (Chen & Han, 2015; Li et al., 2013; Yue, Liu, & Fan, 2010; Zhan & Meng, 2013). Since government plays a key role in the estate development in China and influences developers' behaviors by regulating the floorspace types within areas, spatial floorspace distribution studies are barely conducted in China, especially those about floorspace forecast.

China is now undergoing a fast urbanization process with an increasing number of people pouring into cities. Land use especially real estate-related planning policies would be of great significance under this special context. Since the government's supreme rights in China, studies in consideration of government activities are much more difficult than that in a general market. Most studies carried out focusing on value and density distribution, but few of them focused on the quantitative forecast of urban real estate development. In China, real estate developers and government have dual influences on the floorspace development. But few studies could provide a fine tool to forecast the floorspace development in each year especially in developing countries like China. What possibly happen in the following years given certain planning policies thus deserve exploration. Large room remains for the analyses of floorspace development especially combined with China's national conditions.

In this context, this study builds a three-step Floorspace Development Model (FDM) to forecast the housing floorspace development and distribution in megacities. This development model is to estimate the changes of the available floorspace quantities for housing activity by forecasting the development decisions made during each period. The manuscript is organized as follows: The FDM model is described in Section 2, the floorspace development model establishment for Beijing is analyzed in Section 3, results and discussion are presented in Sections 4 and 5 and followed are concluding remarks of this work in Section 6.

2. Method

The three-step FDM is developed taking full consideration of China's characters in this study. As a kind of useful method, the FDM model is able to forecast developers' decisions in each period and housing floorspace development by year based on both market laws and government spatial planning policies (Niu et al., 2016). This model can be regarded as an essential part linked to LUTI model (Coppola, Ibeas, dell'Olio, & Cordera, 2013; Geurs & Wee, 2004; Simmonds & Feldman, 2011; Wegener, 2004), which is powerful to predict urban spatial development and urgently required for sustainable land use decision making.

The three-step Floorspace Development Model (FDM) forecasts housing floorspace distribution based on permissible development constrains, extant floorspace, and house rents. Since land is usually sold with floorspace permits in China, Permissible Development (PD) constraints are used to represent the ratified types and amounts of housing floorspace. Generally, PD constraint refers to the maximum area that is permitted to develop for each type of floorspace in each zone. It is assumed that developers make decisions based on two factors i.e. the profits made in the last few years and PD constraints. Under these conditions, the housing floorspace development amounts can be projected through three steps as below:

- **Unconstrained total floorspace development.** The total housing floorspace that developers would develop for profit maximization during a period without PD constraints is estimated in this step.
- **Constrained total floorspace development.** The constrained total floorspace and the degree to which developers is restricted by permits are estimated in this step.
- **Floorspace allocation among zones.** The total floorspace areas among zones are allocated in consideration of profitability and permits in each zone.

2.1. Unconstrained total floorspace development

Profitability and the existing floorspace are essential factors in floorspace distribution prediction in the unconstrained development scenario. The amounts of floorspace that developers would develop can be estimated as a fraction of the stock (the amount of floorspace that has been built). The fraction varies according to the profits estimated through lagged rents. An increase in rents in period t will lead to an increase of the development started in period $t + 1$ (given that others are equal and the permissible development area is sufficient). As for year t, the unconstrained floorspace to be developed - $F(U)_p$ in the following period p *(the whole year of $t + 1$)* is obtained based on the following multiplicative formula with a number of variables and a range of time lags y,

$$F(U)_p = \alpha_p \cdot F_t \cdot \prod_{y=N}^{y=0} (r_{(t-y)})^{\beta} \tag{1}$$

where

α_p denotes the scale factor,
F_t denotes the total floorspace stock at time t,
y denotes the number of time lags by year,
$r_{(t-y)}$ denotes the average rent in year $(t - y)$,
β denotes the sensitivity of each variable selected.

Different variables have different sensitivity to floorspace development. Scale factor α in Eq. (1) is assigned as 0.023 according to rule of thumb to forecast unconstrained floorspace development. As for the parameter β in Eq. (1), only zonal averaged rent is chosen to forecast unconstrained floorspace development in this work. As a result, value 1 is adopted for β, which is used to denote the sensitivity of each variable. With detailed data supports, more sophisticated equations can be constructed by introducing additional factors such as interest rates, building cost indexes, and completed development areas in a previous period.

2.2. Constrained total floorspace development

As mentioned above, the floorspace areas that developers can develop are restricted by governmental permits. Thus the total PD constraints across all the zones in period p - $F(P)_p$ is defined as

$$F(P)_p = \sum_i F(P)_{pi} \tag{2}$$

where $F(P)_{pi}$ is the PD constraint of zone i in period p. If the total unconstrained development area $F(U)_p$ in Eq. (1) does not exceed $F(P)_p$, i.e.,

$$F(U)_p \le F(P)_p \tag{3}$$

the total PD constraint will not be applied, and the total constrained floorspace to be developed - $F(C)_p$ will be equal to the unconstrained, i.e.,

$$F(C)_p = F(U)_p \tag{4}$$

If the total unconstrained development area $F(U)_p$ in Eq. (1) exceeds $F(P)_p$, i.e.,

$$F(U)_p > F(P)_p \tag{5}$$

the total PD constraint will be applied and the total constrained floorspace to be developed - $F(C)_p$ will be equal to the permissible one, i.e.,