# Examining the Long-Term Effect of Government Housing Regulations on Spatial Distribution of Residents: A Case Study of Singapore

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## Abstract

One commonly observed issue in the vast majority of Asian cities is economic growth that pushes land prices up, especially in urban and inner-city areas. Consequently, low- and middle-income households are priced out of land markets. As affordable housing in Asia is a serious and considerable challenge, governments have implemented housing programmes, policies and institutional arrangements to provide a range of affordable housing alternatives. To assist policymakers with evaluating urban development policies and anticipating trends in the evolution of cities, researchers have significantly improved modern urban land-use-and-transportation (LUT) models. However, few studies focus on the long-term effect of government housing regulations on the spatial distribution of residents. As a result, policy makers and planners have limited tools to test the spatial consequences of government intervention in housing markets after several cycles of slow/fast economic growth and demographic shifts. In order to fill the gap, this study uses Singapore as a case to examine the eligibility rules for allocating public housing, and to study the spatial pattern of various types of households.

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## 1. Introduction

One commonly observed issue in the vast majority of Asian cities is economic growth that pushes land prices up, especially in urban and inner-city areas. Consequently, low- and middle-income households are priced out of land markets. As affordable housing in Asia is a serious and considerable challenge, governments have implemented housing programmes, policies and institutional arrangements to provide a range of affordable housing alternatives. To assist policymakers with evaluating urban development policies and anticipating trends in the evolution of cities, researchers have significantly improved modern urban land-use-and-transportation (LUT) models. As a result, policy makers and planners have limited tools for testing the spatial consequences of government intervention in housing markets after several cycles of slow/fast economic growth and demographic shifts. In order to model a housing market with heavy government regulations on the demographics of housing purchasers, researchers need to address the issues regarding the relationship between life events and moving behavior. For microsimulation models of neighborhood change, handling these issues can be difficult if the state space of relevant household history becomes unmanageably large.

In order to fill the gap, this study uses Singapore as a case to examine the eligibility rules for allocating public housing, and to study the spatial pattern of various types of households. The intention is to see whether the rules are significant enough to impact household residential relocation choices in ways that have long-term spatial and demographic consequences. This study aims at improving our understanding of the various multi-year economic and spatial impacts of government intervention in housing markets in Singapore. The results would not only improve understanding in places where such strong regulations exist, but also highlight on some key issues that deserve attention when examine the potential for demographic-based housing policies in other contexts. The paper is organized as follows. Section 2 reviews literature on modeling residential relocation behavior and life cycle stages. Section 3 introduces the key features of housing regulations in Singapore. Section 4 discusses the preliminary findings of the demographic phenomenon over time. Section 5 focuses on the modeling implication regarding better incorporating government intervention into traditional LUT modeling framework. Section 6 is the conclusion.

## 2. Literature on Modeling Residential Mobility and Life Cycle Stages

Policy makers and modelers have long recognized the importance of modeling urban travel and land use in an integrated fashion.  During the last few decades, effort has been made to improve integrated urban models in a way that behavior of agents, including their residential location choices and workplace location choices, can be better modeled (Habib 2009). Improvement in modeling residential mobility will allow planners and policy makers to gain more insights on spatial process of neighborhood development and determine demand for public infrastructure and services, including transportation system.

Pagliara and Wilson (2010) review a number of residential relocation models as part of a LUT model, and provide a framework to summarize the modeling approach, treatment of space and decision makers for the varieties of residential location models. Basically, discrete choice models dominate model operationalization. More interestingly, microsimulation begins to appear significantly, including UrbanSim, Oregon2, SimDELTA, given that microsimulation allows for better treatment of heterogeneity among the agents, accounting for more relevant agent characteristics in modeling, and testing more specific policy and pricing instruments. Compared with aggregated methods, microsimulation models simulate the behavior of agents and their interactions with other agents, objects and processes in order to translate believable short-term behavioral assumptions into longer-term patterns and indicators without the ecological fallacy and homogeneity assumptions that plague typical extrapolations of aggregate trends.

In the last few decades, microsimulation models have been widely used to forecast future urban conditions and test policies in different contexts. Several reviews discuss the development of such integrated LUT models and the key features of some major models (Miller et al. 1998; Waddell 2002). However, most of the existing microsimulation models have been developed and used in places where government intervention in the housing markets is relatively modest. These models require major adjustments to be applicable to a place like Singapore, where the housing market is heavily regulated and demographic-oriented. The models need to be adjusted to consider the interactions between housing policies and demographics. Including these interactions requires more information regarding the history of households and housing choices rather than a single "snapshot" of socio-economic characteristics.

Several models in Europe demonstrate efforts to add higher demographic and life course resolution into microsimulation models, with some enhanced possibilities for testing relevant government policies. For example, Jordan et al. (2012) use an agent-based approach to model housing choice and evaluate an urban regeneration policy in the UK. The model includes six rules to identify households' residential relocation behavior, such as ethnic tolerance, the spatial constraint for households to search for new houses, access to schools, etc. The authors test different types of scenarios, such as housing vacancy increases or building new schools, to reflect regeneration policy. By adjusting the combinations of rules to execute under different scenarios, the authors evaluate the effects of regeneration policy on the spatial patterns of households. With a better understanding of the relationship among households, housing units, and economic conditions, researchers can take these multi-dimensional factors into consideration and obtain more detailed market segmentation so as to better capture the heterogeneity of home buyers in the housing markets.

Another example is the dynamic microsimulation model SMILE (Simulation Model for Individual Lifecycle Evaluation) (Hansen and Stephensen 2013). It is developed to evaluate the long-term housing demand in Denmark. SMILE focuses on the feedback effects of household formation on housing demand. To simulate household formation, the model takes three types of events into consideration: demographic, socioeconomic, and housing-related events. By applying the empirical demographic information of Demark, the model examines the impact of some demographic and urban scenarios on housing demand, including changing patterns of cohabitation (a decrease of average household size), increasing urbanization, and aging population.

## 3. Government Intervention on Housing Market in Singapore

Singapore has heavy government control over the housing markets, through direct construction and strict eligibility rules for public housing. In 1960, the Housing and Development Board (HDB) was set up in order to provide 'decent homes equipped with modern amenities for all those who needed them' (Phang 2005). During the past few decades, public housing projects, together with public housing policies, have enabled home ownership for the majority of Singaporeans. In Singapore, the eligibility rules and

priority schemes are among several salient features of the government regulation in the public housing market (Derrible et al. 2011). Table 1 summarizes the basic eligibility rules for HDB new sale purchasers and resale purchasers. Some major criteria regarding applicants' demographic attributes include citizenship, age, household structure, and household income. Applicants to HDB new sale and resale units need to be Singaporean citizens or permanent residents. Residents, who are over 21 years old, are eligible to apply for new HDB flats in various locations except for singles. Single citizens above the age of 35 are allowed to purchase HDB 2-room flats in nonmature HDB estates. In addition, families with very high household income are ineligible to apply for new HDB dwellings. It is evident that with the housing shortage eased, the government relaxed the eligibility rules for purchasing new and resale HDB flats over time (Phang 2005). For example, the household income ceiling was increased from $1,000 per month in 1964 to the present $10,000. The minimum occupancy period (MOP), as a means to regulate the demand, was changed from five to ten years in 1997 to reduce demand and then shortened from ten to five years.

**Table 1.** Eligibility for Purchasing an HDB New Sale or Resale Flat (As of July 2014)

|  | New Sale | Resale |
|---|---|---|
| **Flat Type** | **2-room, 3-room, 4-room, 5-room, executive flat** | **All** |
| **Citizenship** | - Application must be a Singaporean citizen<br>- Family Nucleus must contain at least another citizen or permanent resident (PR) | - Applicant must be a Singaporean citizen or PR<br>- Family nucleus must contain a citizen or PR |
| **Age** | At least 21 years old | At least 21 years old |
| **Family Nucleus / Structure** | - Applicant, Spouse, Children<br>- Applicant, Parents, Siblings<br>- Applicant, Children<br>- Applicant, Fiancé(e)<br>- Applicant (orphan), Siblings | - Applicant, Spouse, Children<br>- Applicant, Parents, Siblings<br>- Applicant, Children |

| Household Income Ceiling | - 2-room: SG$5,000* <br> - 3-room (non-mature town or estate): SG$5,000 <br> - 3-room (mature town or estate) and above: SG$10,000** (SG$15,000 for extended families***) | - No ceiling unless apply for CPF grant |
|---|---|---|
| Owner in other property | - No ownership in private property for at least 30 months before application | - Disposal within 6 months of completion of purchase |
| Owner or Ex-owner HDB regulated flat | Singaporean households can only buy any of the following twice: <br> - Flat from HDB <br> - Resale flat using CPF <br> - DBSS flat or EC from developer | |

**Note:**
* The income ceiling was increased from $2,000 to $5,000 to give more families the options to buy such flats.
** With effect from 15 August 2011, the HDB changed the monthly household income ceiling for purchasing of new flats from $8,000 to $10,000. The $8,000 income ceiling was implemented in 1994.
*** The income ceiliing for extend family revised upwards from $12,000 to $15,000.
(Source: Derrible et al. 2011 and updated by the authors)

Another channel of government intervention is through the housing location processes. HDB gives priorities to first time buyers and households meeting certain life cycle stages, such as newly weds, couples with children as first time buyers, and couples with more than two children, during the housing lottery processes. Presumably, government regulations create distinct housing options for different types of households. For example, newlyweds that are eligible for HDB units and enjoy priority to purchase HDB units may choose between moving away from the central region to a large public housing unit in 3-4 years (which is the typical waiting time for new HDB housing units) or moving to a small resale unit in a central or peripheral area without waiting. For typical HDB eligible households without priority, it is possible that even though they prefer a new HDB unit, it may take longer than three years to move in because they need to enter a lottery multiple times to win one assignment. For non-HDB eligible households, they must enter the private housing market.

Recent studies examining government intervention on public housing in Singapore cover several aspects: submarkets and residential mobility

(Bardhan 2003), economic challenges (Phang 2007; Chua 2014), social impacts (Yuen 2005), and international comparison (Phang 2005). Despite that the government regulation on the public housing market in Singapore is demographic-oriented, there are very limited studies examining the spatial and demographic consequences of housing policy in Singapore (Jones 2012). The question about how a government-regulated housing system like Singapore may expand or limit the opportunities to move for individuals, and whether there are any spatial and demographic consequences, is not well understood and has not been studied yet. Understanding the spatial and demographic consequences of government intervention on the housing market has significant practical value for urban planners and housing policy makers. If one ignores this aspect, the current housing policy may potentially lead to negative demographic changes in the existing public housing towns, such as demographic segregation, mismatching between public infrastructure and people, and ineffective urban redevelopment, as well as decentralization incentives that could have adverse mobility consequences.

## 4. Spatial Distribution of Singaporean Residents

Given the complexity of modeling residential mobility, data limitation, and behavioral uncertainty, we explore various datasets about households' residential relocation to identify which residential mobility patterns might lead to short and long term spatial heterogeneity, and which behaviors might be significantly impacted by government regulations. By utilizing 2000 and 2010 Singaporean Census data at the planning area level, we generate measurements and use a longitudinal representation to capture the regularities of spatial and temporal demographic patterns. The preliminary results demonstrate several interesting features of moving patterns of Singaporean residents: 1) heterogeneity of households' moving behavior, 2) regulatory effect on age composition of HDB estates, and 3) long-term accumulative effect on age composition across HDB estates.

### 1) Heterogeneity of Households' Moving Behavior

Using available data, we find two significant features regarding Singaporean residents' moving behavior, including distinct moving tendency by households across age groups and households' moving preference towards housing types.

### a) Distinct Moving Tendency by Households Across Age Groups

According to the literature of household mobility, age is a crucial factor in determining households' relocation tendency and frequency. For instance, young adults between the ages of 20 and 35 are the most mobile segments of the population (Dieleman 2001). In order to understand whether Singaporean households behave similarly as households elsewhere, we first examine the relationship between the ratios of households that shifted homes and the age group of household heads (Table 2). The numbers show that as age increases, the ratios of households that shifted homes in each age cohort decrease, which is consistent with the general moving tendency of age groups in other housing market contexts. Overall, 58% of households moved between 1990 and 2000. Households headed by adults within the age group—below 35—have the highest proportion of households that shifted homes. In contrast, only 25% of the households headed by adults who are 65 and over shifted their dwelling units. This implies that an age effect exists as a determinant of moving tendency.

In addition, from the behavioral perspective, Singaporean households exhibit similar age-related behavior in the process of residential mobility compared with other housing market contexts, such as the United States (free market) and Northwest Europe (regulated market). However, the proportion of households in various age groups who move over a decade may vary across regions and countries due to the local variation in housing markets, state policies, and economic development.

**Table 2.** Statistical Summary of Households Shifting Homes by Age Groups between 1990 and 2000

| Age Group In 2000 | Total Number of Households | Column Percentage (%) | Number of Households Shifting Homes | Moving Percentage (%) |
|---|---|---|---|---|
| Total | 915,090 | - | 530,985 | 58.0 |
| Below 35 | 140,024 | 15.3 | 122,152 | 87.2 |
| 35-49 | 430,027 | 47.0 | 294,548 | 68.5 |
| 50-64 | 240,383 | 26.3 | 87,671 | 36.5 |
| 65 & Over | 104,657 | 11.4 | 26,614 | 25.4 |

(Source: SingStat 2000)

### b) Moving Patterns between Housing Types

In order to examine the relationship between households' housing history and moving patterns, a common way is to extract information regarding the

origins and destinations of moving using a cross-section of households. The matrix generated describes which kinds of transitions take places in the housing consumption when households move. This kind of table is important because it links households' housing behavior to their housing events/history. The historically observed moving patterns allow us to estimate transition probabilities so as to model households' moving behavior more accurately. Table 3 presents the moving matrix of the total resident households[1] in Singapore between 1990 and 2000. In this table, the numbers in the diagonal (marked in yellow) represent the proportion of moving that are equivalent moving (moving between the same type of dwelling). The green area indicates the proportion of upward adjustment (to bigger homes), whereas the red area indicates the proportion of downward adjustment. Uncolored section indicates it is hard to define upward or downward adjustment between dwelling types in the private market.

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[1] Resident households refer to households headed by Singapore citizens and permanent residents, excluding foreigners.

**Table 3.** Percentage of Households Who Moved between 1990 and 2000 by Old/New Housing Type

| Type of Previous Dwelling | | Total (Column %) | Type of Current Dwelling | | | | | | | | | | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | HDB Dwellings | | | | | | | Private Properties | | | | | |
| | | | 1-Room | 2-Room | 3-Room | 4-Room | 5-Room | Executive | Others | Bungalows | Semi-Detached | Terrace | Condo & Private | Row%* | N |
| Total | | 100 | 2 | 3 | 20 | 33 | 21 | 9 | 0 | 0 | 1 | 2 | 8 | 100 | 530,985 |
| HDB | 1-Room | 4 | 15 | 11 | 36 | 30 | 7 | 1 | 0 | - | 0 | 0 | 1 | 100 | 20,578 |
| | 2-Room | 4 | 4 | 12 | 34 | 37 | 10 | 2 | 0 | - | 0 | 0 | 1 | 100 | 22,297 |
| | 3-Room | 33 | 1 | 3 | 23 | 44 | 22 | 5 | 0 | 0 | 0 | 0 | 2 | 100 | 175,400 |
| | 4-Room | 29 | 1 | 2 | 19 | 35 | 27 | 11 | 0 | 0 | 0 | 1 | 4 | 100 | 153,472 |
| | 5-Room | 12 | 0 | 1 | 14 | 24 | 28 | 16 | 0 | 0 | 1 | 3 | 12 | 99 | 64,979 |
| | Executive | 4 | 0 | 0 | 8 | 19 | 19 | 21 | 0 | 0 | 2 | 7 | 21 | 99 | 21,220 |
| | Others | 0 | 3 | 6 | 35 | 33 | 7 | 5 | 4 | - | - | 2 | 4 | 99 | 854 |
| Private | Bungalows | 1 | - | 0 | 11 | 13 | 11 | 7 | 0 | 12 | 10 | 8 | 25 | 97 | 6,492 |
| | Semi-Detached | 2 | - | 0 | 11 | 14 | 15 | 10 | 1 | 6 | 14 | 6 | 20 | 97 | 8,243 |
| | Terrace | 3 | 1 | 1 | 14 | 19 | 17 | 9 | 0 | 2 | 8 | 11 | 16 | 98 | 14,776 |
| | Condo & Private | 6 | 0 | 1 | 11 | 13 | 10 | 5 | 0 | 2 | 5 | 7 | 43 | 98 | 29,443 |

(Source: SingStat 2000)

Note: * The original categories include *HUDC/Govt Executive Flats* and *Others*. Because they do not shown up in the table, therefore, the total percentages added up could be less than 100.

There are three major findings from the matrix of overall moving pattern in Singapore:

i.    Within the public sector, the row totals indicate that moves from 3-room and 4-room flats are far more frequent than moves from other housing types. There are two factors to explain this phenomenon: the first one is a large proportion of the dwelling units occupied by resident households are 3-room and 4-room flats during that period. The second one is compared with other dwelling types, households that are most mobile mostly resided in 3- and 4-room flats. Both of the factors could play a role in forming this moving pattern due to the governmental intervention on the housing supply and allocation rules.

ii.    Upward adjustments in the public housing market are much more frequent than downward adjustment. 4-room units are a significant destination for moves from origins of smaller units in the public sector. Condo & private and 4-room HDB flats are a significant destination for moves from origins in the private sector. According to the housing literature, the upward movement among households commonly exists in other market contexts as well (Clark and Dieleman, 1996). However, in Singapore, the upward adjustments could be an outcome of both the motivation of upgrading to better living conditions from bottom-up and the regulatory effect given the government greatly encourages households to upgrade if needed.

iii.    According to the numbers in the diagonal, equivalent moving happened frequently for 4-room, 5-room and executive HDB flat dwellers, which means location changes occurred when they moved out but the housing type did not change. This phenomenon shows that even though upward moving would bring households positive utility in terms of the increased size of dwelling and government subsidies, location changes can also generate significant benefits to households. The same reason can also explain why some households choose downward adjustments.
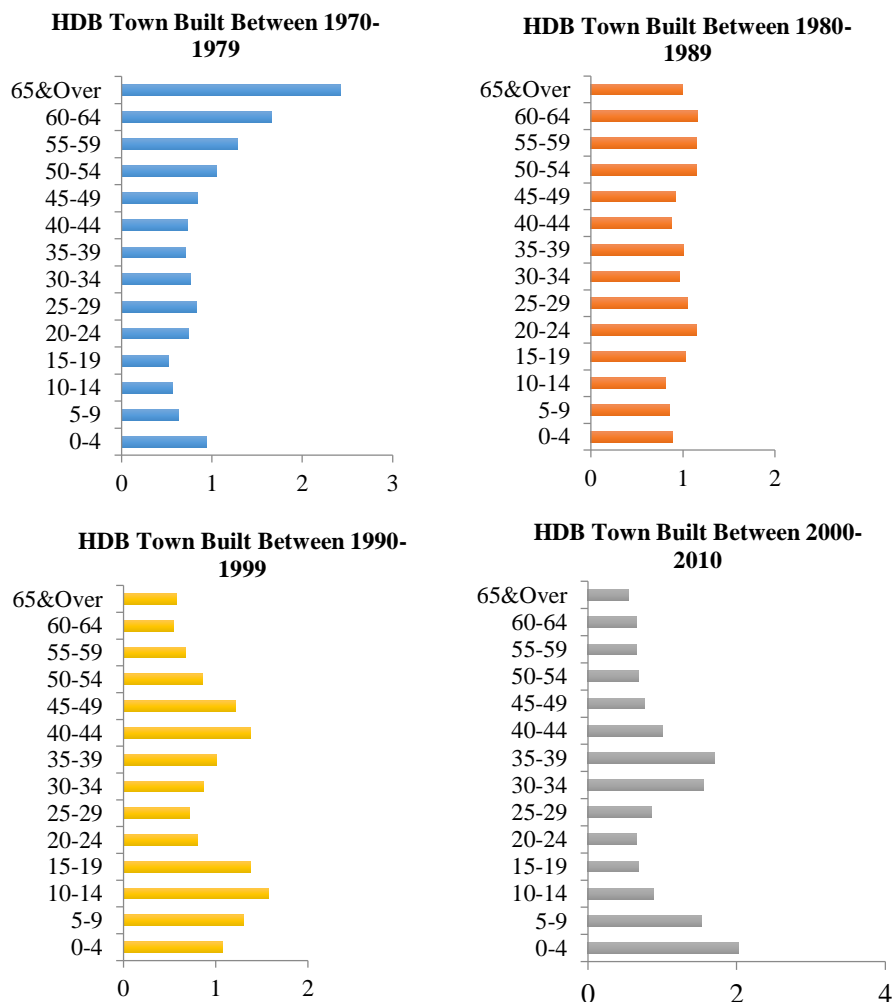
## 2) Regulatory Effect on Age Composition of HDB Estates

As Singapore's government has a made concerted effort to boost home-ownership by building public dwelling units and selling to Singaporeans at a subsidized price, there are a significant number of households with eligibility priority who move to newly built HDB towns each year. One key

question is whether there are any demographic consequences that demonstrate itself geographically? This question aims at showing an indirect impact of government housing policies on demographics. By using the Singaporean census data in 2010, we find that some neighborhoods exhibit a demographic bulge whereby certain demographic groups are overrepresented in certain neighborhoods compared with the Singapore total. Specifically, we apply the idea of location quotients (LQ), typically used to compare regional industry compositions, to examine the concentration of age groups in Singapore. The formula is shown as below:

$$LQ_i = \cfrac{\cfrac{\textit{Population in age group i in zone t}}{\textit{Total population in zone t}}}{\cfrac{\textit{Population in age group i in the country}}{\textit{Total population in the country}}}$$

We apply the LQ to demonstrate distinctions across age groups in HDB estates that were built in four time periods: 1970-1979, 1980-1989, 1990-1999, and 2000-2010 (Fig. 1).

**HDB Town Built Between 1970-1979**

**HDB Town Built Between 1980-1989**

**HDB Town Built Between 1990-1999**

**HDB Town Built Between 2000-2010**

**Fig. 1.** Location Quotients across Age Groups by HDB Towns built in Four Periods (1970-1979, 1980-1989, 1990-1999, 2000-2010)

The key idea is to examine, for an HDB town built in a certain period, if there is a corresponding population bulge of a specific age group(s). The answer is yes. For instance, a HDB town built between 2000 and 2010 has shown a concentration of age cohorts: 0-4, 5-9, 30-34, and 35-39. Similarly, HDB towns built between 1990 and 1999 are concentrated with residents aged 10-14, 15-19, and 40-44, and 45-49. This pattern is consistent with the government's goal that the public housing system encourages first-time buy-

ers, presumably young couples and their kids, to own new HDB flats. More-over, the age cohorts clustered in the towns built between 1990 and 1999 are groups that are exactly ten years older than those in the towns built between 2000 and 2010. This could indicate the persistency of the initial demo-graphic patterns over time in HDB towns.

In contrast, for an HDB town built between 1970 and 1979, the population bulge appears at the age groups: 55-59, 60-64 and 65 and over. One potential explanation is that the elderly residing in the old towns purchased their HDB units at an early age and aged in the same residence. There is no clear con-centration of age groups in the HDB towns built between 1980 and 1989. This suggests that the demographic bulges of these HDB towns have miti-gated as time passed, and the demographic patterns formed when the estates first opened have been largely washed out.

## 3) Long-term Accumulative Effect on Age Composition across HDB Estates

Another important finding from analyzing these 2000 census data, which reports the population by each age group in each planning area[2], is the ex-istence of regional bulges of young children (aged 0-4) and elderly (aged 65 and over) (Figure 2). In particular, in the ranking of planning areas for the LQ of age group 65 and over, planning areas located in the central region have a value more than 1.5, meaning that the proportion of elderly living in these planning areas is 1.5 times more concentrated than the Singapore-wide average. In contrast, the value of LQ of elderly in the peripheral planning areas, where new towns are concentrated, is quite low. This means those planning areas have a sparse population of elderly. On the other hand, in the ranking of planning areas for the LQ of age group 0 to 4, planning zones with an LQ higher than 1.5 are concentrated in north and northeast of the country. Meanwhile, planning areas with relatively low LQs of young kids (aged 0-4) are in the central region. It is worth noting, that planning zones with a high concentration of young kids are primarily the ones with low concentration of elderly.

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[2] According to the definition of planning boundaries from the Urban Redevelop-ment Authority (URA), there are a total of 55 Planning Areas in Singapore with each Planning Area served by a town center and several neighborhood commer-cial/shopping centers. According to the census, 35 of these planning areas had res-idential populations during 2000 and 2010.
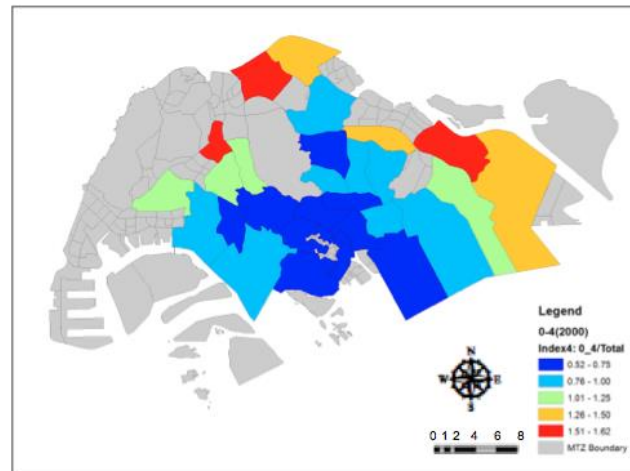
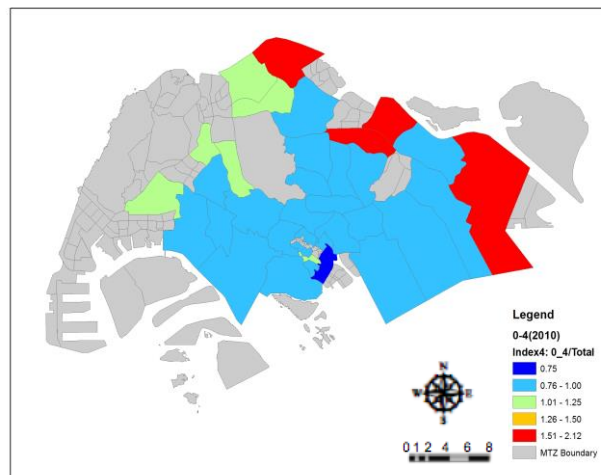**a) Location Quotient of Age Group 0-4 in 2000**
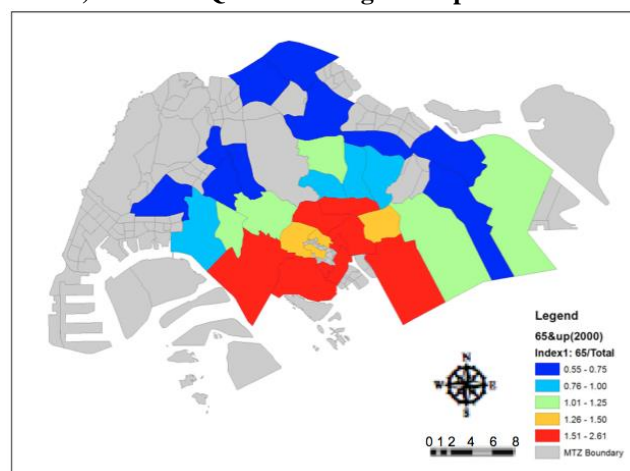


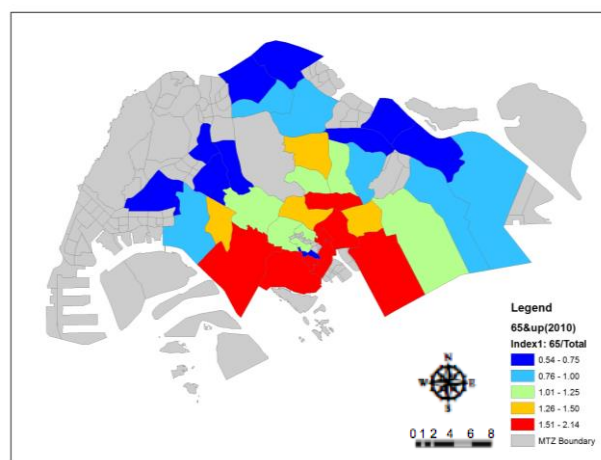**b) Location Quotient of Age Group 65+ in 2000**

**Fig. 2.** Location Quotient of Age Group 0-4 and 65 and Over by Planning Areas in 2000

More interestingly, these bulges persist across years. In particular, we can map the values of the same measurement—LQ—in 2010 using the same cut off points (Fig. 3). A clear trend is that during the 10-years period between 2000 and 2010, the elderly became more concentrated in the central region, whereas young children became more clustered in the peripheral regions. The mechanism that is responsible for the formation of demographic bulges of certain age groups and the persistency of such demographic bulges are multi-faceted. On the one hand, individuals' moving behavior is consistent

with research in other market contexts (Clark and Dieleman, 1996). As demonstrated early in this section, young adults are the most active demographic group in terms of changing residence, and a majority of households that shift homes, upgrade to larger dwelling units.



**a) Location Quotient of Age Group 0-4 in 2010**



**b) Location Quotient of Age Group 65+ in 2010**

**Fig. 3.** Location Quotient of Age Group 0-4 and 65 and Over by Planning Areas in 2010

On the other hand, given that a significant number of households that enjoy eligibility priority according to their life course stages move to newly built public housing towns each year, public housing towns built in different

years exhibit distinct age compositions. For example, for a public housing town built between 1970 and 1979, the population bulge appears at the age groups 55 and over. This indicates that the spatial concentration of age groups could be an indirect outcome of the interaction between market and governmental forces.

## 5. Modeling Implication for Incorporating Government Intervention on Housing Market

Policy makers and modelers have recognized the importance of modeling urban travel and land use components in an integrated fashion, because complex urban issues such as urban sprawl and smart growth relate to both land use and transportation. Improvements in modeling households' residential relocation choices have played a key role in increasing the forecasting capability of current land-use-and-transportation models. However, most of the existing integrated microsimulation models do not explicitly model the government intervention on housing markets at the individual level. If we apply such an integrated model to a region where the housing market is heavily regulated and demographic-oriented, the model needs to be adjusted to consider policy interactions and demographics. Including these factors require more information regarding the history of households and housing choices rather than a single "snapshot" of socio-economic characteristics.

In the residential mobility literature, researchers use variables, such as which life cycle stage a household was at before move and what life cycle events occurred after moving to a new location to capture the life cycle effects (Clark 2012). In Singapore, building the connection between life cycle events and residential relocation is difficult because for a household, the change of its residential location always occurs several years after this household applied and won an HDB dwelling that satisfies their needs. And the priority is given based on the life cycle stages of this household at that specific, historical point of time. So if we include the variables, such as marital status change (e.g. whether became married after moving), we may not see the change occur because it happened when they bid for a yet-to-be-built HDB dwelling, years before they moved. Therefore, an adjusted residential relocation model for Singapore needs to include more variables regarding the history of a household's life cycle events, together with other demographic characteristics, such as changes of income, or change of household size. Meanwhile, there are constraints of including additional variables to record the historical information of households and housing. When updating

individuals' and households' information for simulation, these additional variables need to be retained in the reference sample. If too many variables were included, such as years of residing in the current dwelling, years of being married, and years of having children, the contingency table that is used to generate synthetic population will grow exponentially, which could severely compromise the methodologies used to develop fully-attributed synthetic population.

Besides, as most of the LUT models use annual kill-and-clone adjustments to track exogenously specified demographic trends, this method may undo the spatial effects of life cycle patterns, such as the demographic bulge in this study. Particularly, the kill-and clone method does not age individuals in the synthetic population. What the method does is the kill some individuals and clone new individuals from the existing synthetic population in order to match exogenously specified control totals for each demographic group. There are two problems with such a method. The first one is the historical information associated with individuals, such as length of staying in the current dwelling, or length of being married, could be lost at the end of year. For example, for a 30 years old individual in the synthetic population in year t, this individual will stay as 30 in year t+1 in the synthetic population, and the corresponding information about length of stay in the current dwelling will be unchanged. However, in reality, the history regarding household structure and housing condition could be important factors in predicting households' moving propensity. The second problem is that a newly generated synthetic household is usually located using a housing choice model that includes minimal household history. Therefore, the spatial patterns of demographic composition at a spatially disaggregated level could be washed out after updating the synthetic population using the kill-and-clone adjustments. How to tweak the existing kill-and-clone strategy in urban microsimulation models so that the spatial consequences of life cycle effect on residential mobility can be retained is a question that deserves further attention and investigation.

## 6. Conclusion

In the Singapore case, the government housing regulations favor households at certain lifecycle stages, such as newlyweds or households with kids, with basic eligibility established by an age threshold. They grant priority to those households during the public housing lottery processes. Therefore, the different moving rates across age groups reflect the regulatory impact, but

age groups are not the direct mechanisms through which the policies work. What the policies really influence are the moving tendencies for households at different life cycle stages. However, capturing the interaction between life cycle events and residential relocation choices is not an easy task.

The research findings show that in order to model a housing market with heavy government regulations on the demographics of housing purchasers, researchers need to address the lifecycle and moving behavior issue. In particular, when housing demand is closely associated with lifecycle events, the question that what minimal history of demographics and housing choices needs to be included in addition to the cross-sectional snapshots of current demographic and residence characteristics in a residential relocation model becomes crucial. Further research is needed to determine whether minimal extensions to current modeling approaches can capture history in sufficient detail that LUT models, with kill-and-clone adjustments, can properly account for key lifecycle patterns and regulations without requiring a full-blown cohort survival model of demographic change.

## 7. Acknowledgment

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