A Design of the Public Housing Policies through the Dynamic Analysis of the Intra-Urban Migration Structure

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Abstract

To construct more public houses so that the low income population in the urban areas can have their own houses is one of the major efforts of the government of the Republic of China on the island of Taiwan. This good-will policy did solve some of the housing problems, yet remained some undesirable ones, such as, the large amount of unsold public houses. Those unsold public houses were primarily due to (1) delayed supply, (2) smaller sizes, and (3) unsuitable locations. This research attempts to study the "unsuitable location problem" and "too small size problem" in the city of Kaohsiung. The System Dynamics methodology is employed to study these problems through model building and policy testing. The model is composed of three sectors: (1) population and the zonal migration attractiveness, (2) housing supply, and (3) housing demand. All the three sectors are interacted with each other. The selection of the variables and the weight of variables are partly determined by field survey. By focusing on the structure of intra-urban migration, it is found that the intra-urban system has a very dynamic feature. The simulation results show that the behavior of the population flow is dominated by several feedback loops, some reinforce the growth of population, while others limit it. Through analyzing the simulation results of the model, some design principles of the public housing policy are suggested. From the demonstration of some policy tests, it shows us the potential of the model to aid the formulation of a "dynamic" public housing policy design, that is, when to supply how much of a certain level public houses to which area of the city under a specific scenario. This preliminary study shows that system dynamics is not only a useful tool to have insights into this kind of complex socioeconomic problems,. but also has the potential to deal with the spatial dimension of urban issues in addition to its mostly temporal applications.

1. Introduction

To construct more public houses so that the low income population in the urban areas can have their own houses is one of the major efforts of the government of the Republic of China on the island of Taiwan. This good-will policy did solve some of the housing problems, yet remained some undesirable ones, such as, the large amount of unsold public houses. Those unsold public houses were primarily due to (1) delayed supply, (2) smaller sizes, and (3) unsuitable locations.

For the delayed supply, as shown in Figure 1, assuming a two years' 10% increment of housing demand, which will be supplied by the constructed houses and the houses planned to construct. The sales of the constructed houses reduce the level of unsold houses, while the sales of the houses planned to construct will raise the perceived sales ratio by construction companies, which then pulls construction companies to build more houses with higher prices. However, owing to bounded rationality, those construction companies can't correctly estimate the empty house effect and the transferred house effect, so, they will supply houses more than 10%. Those surplus houses will be completed after a period of time, which further increase the level of unsold houses. In the mean time, the increased prices will further lower the purchasing power of the low income population, as indicated by the realization fraction in the figure. The city government will then be forced, after some time lag, to start to supply more public houses, which will be completed after another time lag. As a result, a large amount of public houses will be completed during the higher level period of unsold houses in the market. This is what we called the delayed supply problem, which was continuously occurred during the past decades.

The rapid economic growth in Taiwan in the recent years made the problem more complicated. The raised standard of the qualitative housing demand results in the poor sales of houses with too small size or unsuitable location which were in fact mostly public houses.

In this research, we try to study the "unsuitable location problem" and "too small size problem" in the city of Kaohsiung with current population of 1.4 million. The System Dynamics methodology is employed to study these problems through model building and policy testing, which will be introduced in the following sections.

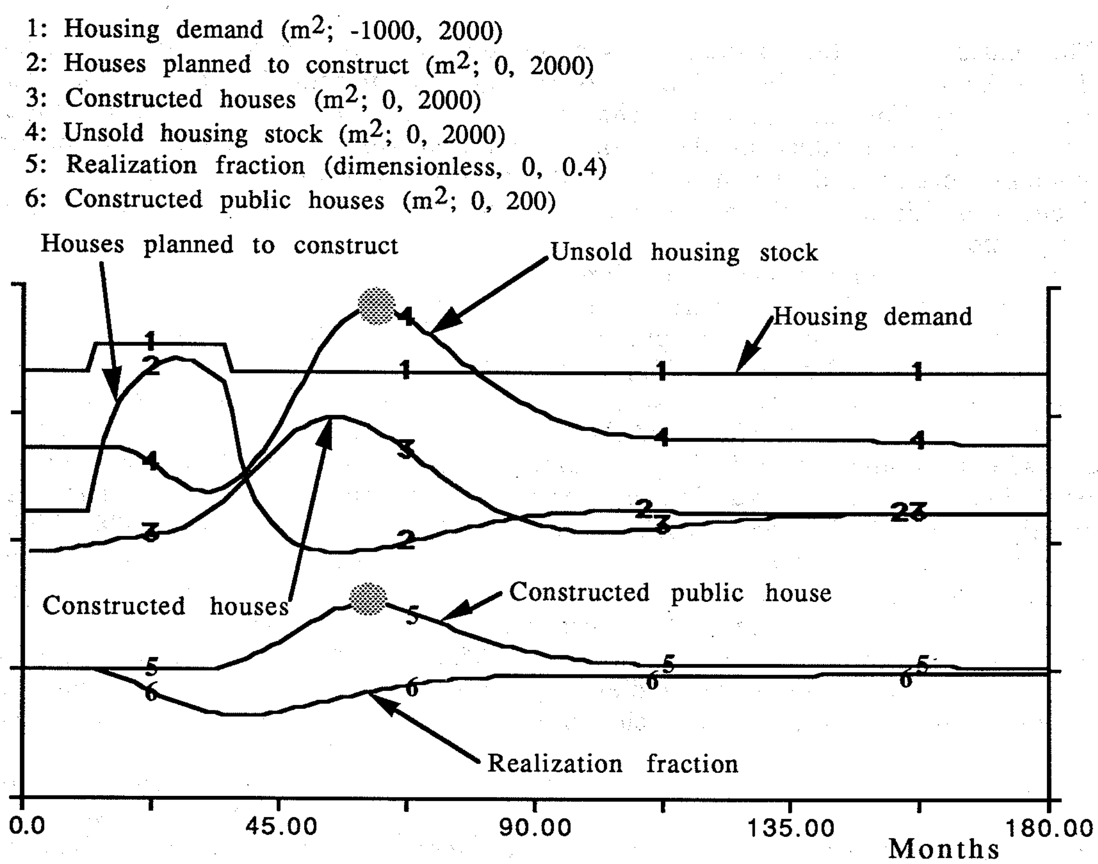

Figure 1: The poor sales of public houses from cyclical perspective

Source: Wang, S. F., S. H. Lo and S. H. Young. 1991. Cyclical Behavior in Real Estate Market: A System Dynamics Model with Micro-structure Approach, *Proceeding of the Fourth International Conference on Comparative Management.* National Sun Yat-Sen University, Kaohsiung, Taiwan, R. O. C.

2. Model Overview

The model is composed of three sectors: (1) the population and the zonal migration attractiveness sector, (2) the housing supply sector (including public housing supply), and (3) the housing demand sector (including the public housing demand). All the three sectors are interacted with each other. The selection of the variables and the weight of variables are partly determined by field survey. The birth rate and the death rate in the urban area is assumed to grow in a certain rate.

Among these sectors, the population and the zonal migration attractiveness sector is in fact the core of the model. The model treats the urban area as a non-homogeneous system. The study area is divided into three zones, namely the Central Area, the Middle Area, and the Outer Area in accordance with the population density and the migration rate. The zonal population are shifted according to the zonal attractiveness which then form the dynamic structure of intra-urban migration. The immigration from outside the urban area are distributed by the fraction of the zonal attractiveness as well.

Intra-Urban Migration Structure

The basic conceptual structure used in this research describing the intra-urban migration behavior is, in fact, similar to the general formulation of the migration structure used by Forrester (1969). That is, the migration (of one socioeconomic class) equals to the product of the normal migration amount of population (of one socioeconomic class) and the migration attractiveness multipliers. And the attractiveness multipliers will be affected by the amount of population after a certain period of time.

However, the intra-urban migration attractivenesses are somewhat differ from the urban-suburban migration attractivenesses. The later includes the attractivenesses of housing, jobs, public services (or public expenditure), population composition, and taxes (Forrester, 1969; Laird, 1974). It is clear that the taxes and the job opportunities in the same city should be equal, but the housing condition, the public services (e.g., the traffic condition) and the population composition may be different within various areas in city. Some of the basic researches had shown that the population composition, varying by their socioeconomic status, will affect the internal migration in one area (Mosekilde, et al., 1985; Reiner, et al., 1988; Richardson and Sterman, 1988). Therefore, the intra-urban migration attractivenesses may contain the housing condition, the public services, and the population composition.

In traditional urban models, the accessibility is one of the most important index to predict the intra-urban population flow, and Thus should be included in the model. In addition, as suggested by some studies (e.g., Smith, 1977; Nelson, 1978), since the environmental factors do affect the choice of residential location, they are also included in the model.

To sum up, the intra-urban migration attractivenesses may include the housing condition, the public expenditure, the population composition, the accessibility condition, and the environmental factors in the general case. However, since the attractiveness of population composition is not so significant in the city of Kaohsiung, Taiwan, it is not included in the model.

Figure 2 shows conceptual diagram of the intra-urban migration structure of the city of Kaohsiung. Where the population flow within the city and the net in-migration from outside the urban area are relocated to the three zones by the population relocation function. The accessibility model of Hansen (1959) suggested that the growing number of population in one specific area is proportional to the total growing number of population in the city, which is determined by the fraction of the accessibility and land availability in one specific area compared to the summation of the accessibilities and land availabilities of all the areas.

$$G_i = G_{Total} \left(\frac{L_i A_i}{\sum_i L_i A_i}\right) \tag{1}$$

where

G_i : population growth in zone i

G_{Total} : population growth total

L_i : land availability in zone i

A_i : accessibility in zone i

Equation (1) suggests that the migration (or population growth) is proportional to the attractiveness of accessibility and is limited by land carrying capacity. The two terms L_i and A_i suggest a attractiveness-capacity concept . From the dynamic view, the two terms indicate a growth-limits process shifting over time by the attactiveness-capacity multi-loops. Therefore, the two terms can be combined to form a integrated migration attractiveness index, which governs the positive and negative loops of population migration. Thus, equation (1) can be reformulated as:

$$M_i = M_{Total} \left(\frac{\text{Attractiveness}_i}{\sum_i \text{Attractiveness}_i}\right), \tag{2}$$

where

M_i : population relocated to zone i

M_{Total} : relocating population in the urban area

Attractiveness_i : integrated migration attractiveness index of zone i

As discussed previously, the attractiveness of intra-urban migration includes not only accessibility, but also the housing condition (or housing capacity, determined primarily by the land carrying capacity), the environmental condition (or environmental capacity), the public expenditure, and the population composition (although not included in the model of Kaohsiung). The relationship between the integrated attractiveness and the population in the model is shown in Figure 3. There are several feedback loops in Figure 3. On one hand, more population in the zone i, through the economic mechanism, leads to more public expenditure and private investment, which then increases the potential future development, the accessibility, the community living environmental condition, and the housing availability in this zone. The investment will attract more population and investment consequently. On the other hand, owing to the limitations of the environmental capacity, the traffic capacity, and the housing capacity, more population in zone i lowers the attractiveness and slows down the growth (sometimes even the decrease) of population.

Housing demand and supply

In this research, housing need is defined as households who need houses to live; housing demand is defined as households who want and can afford to buy houses. Housing demand and housing need are linked by a realization fraction in the model (housing demand is the product of housing need and the realization fraction). Housing need is primarily determined by population. Housing demand is satisfied by the supply of the public housing projects or the supply of the private houses, which is determined by the market share of the public houses and the private houses. The itself, and the house's location. The housing prices will be affected by the cost of land, which will be influenced by the population density in this zone.

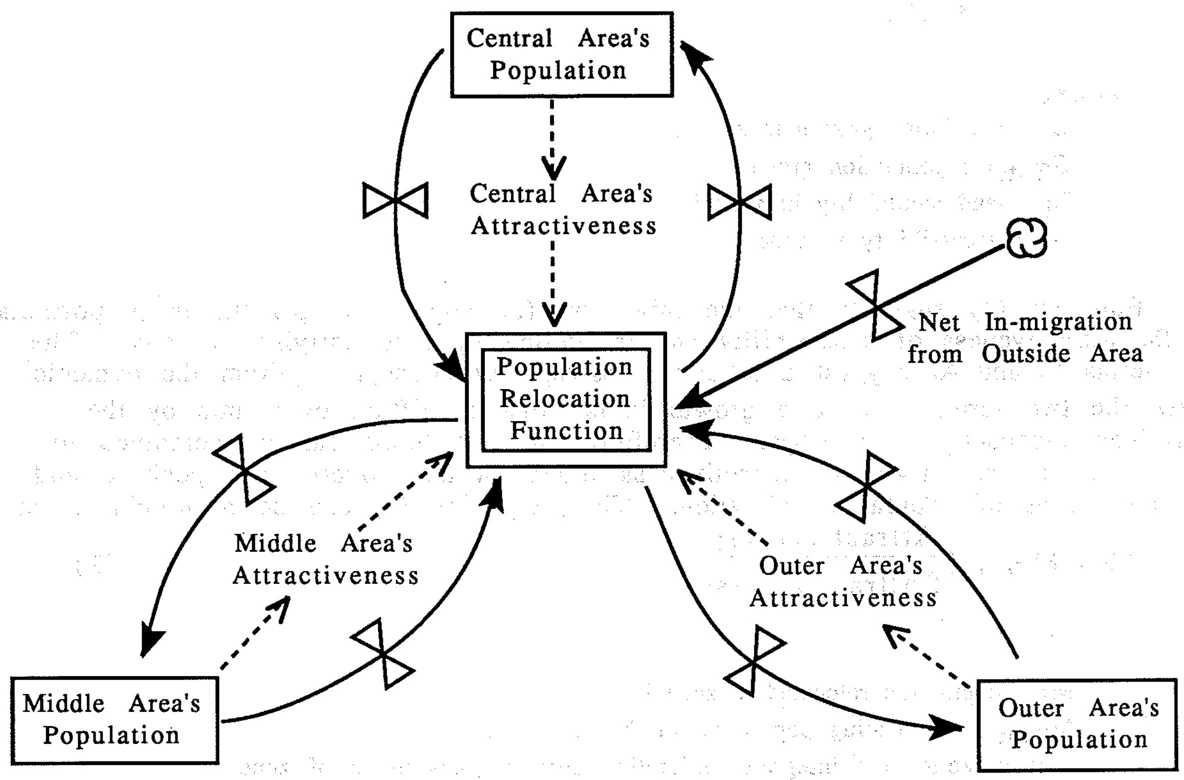

Figure 2: Conceptual Diagram of the Intra-urban Migration Structure

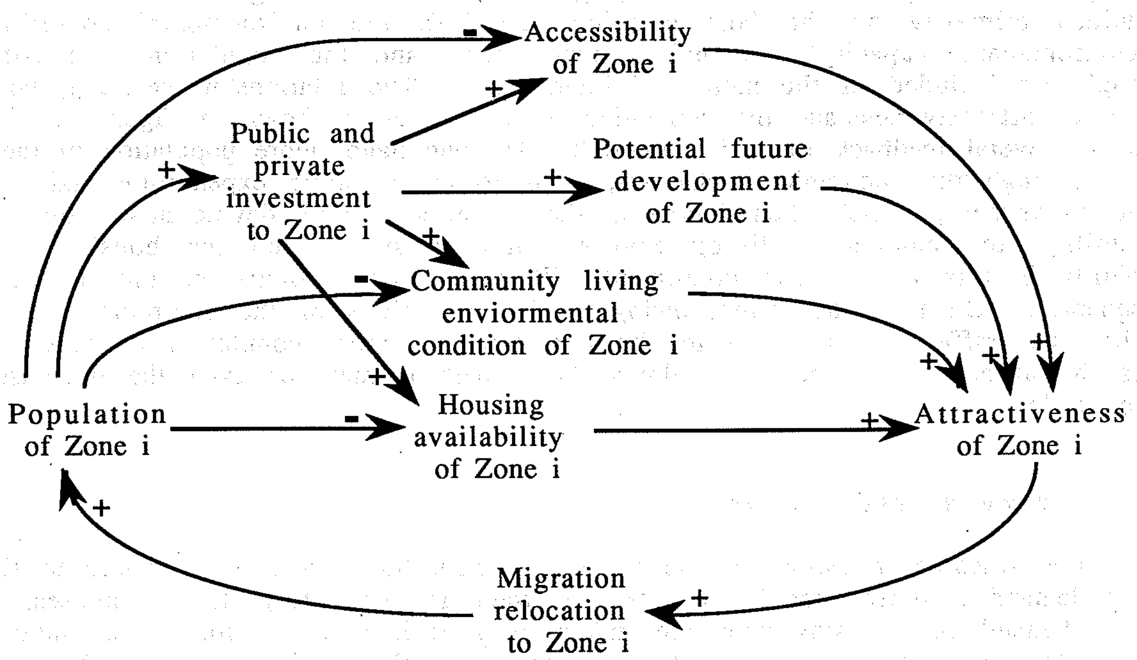

Figure 3: Simplified Causal Diagram of Zone i's Attractiveness Structure

The supply of private houses is controlled by the housing demand, while the supply of public houses is treated as one policy issue. Both the supply of private house and public house will affect the attractiveness of housing availability, which influences migration and then changes the housing need and housing demand in this zone consequently.

3. Model Behaviors and Design Principles

The population densities in the three studied zones are: 316 capita per hectare (Central Area), 136 capita per hectare (Middle Area), and 90 capita per hectare (Outer Area) at the end of 1985, which was also the start time in the simulation. The effectiveness of public housing policy is evaluated by the adequate level of public housing inventory, since too much inventory leads to high inventory cost, on the other hand, too little inventory results in unsatisfied public housing demand. The behaviors of the model and the demonstrations of policy design are shown below. Some design principles of the public housing policies analyzed from the simulation outputs follows.

Base Run: Growth Limited by Capacity

Due to the limitation of the environmental capacity, the traffic capacity, and the housing capacity, the population of the Central Area will grow slowly during the first ten years, then become almost steady in the next ten years. However, because the population densities of the Middle Area and the Outer Area are much lower than the Central Area, the population growth during the next twenty years will concentrate in these two areas, as shown in Figure 4.

1, 2, 3: population (person; 0, 1000000)
4, 5, 6: public housing inventory (m^2; 0, 2000)

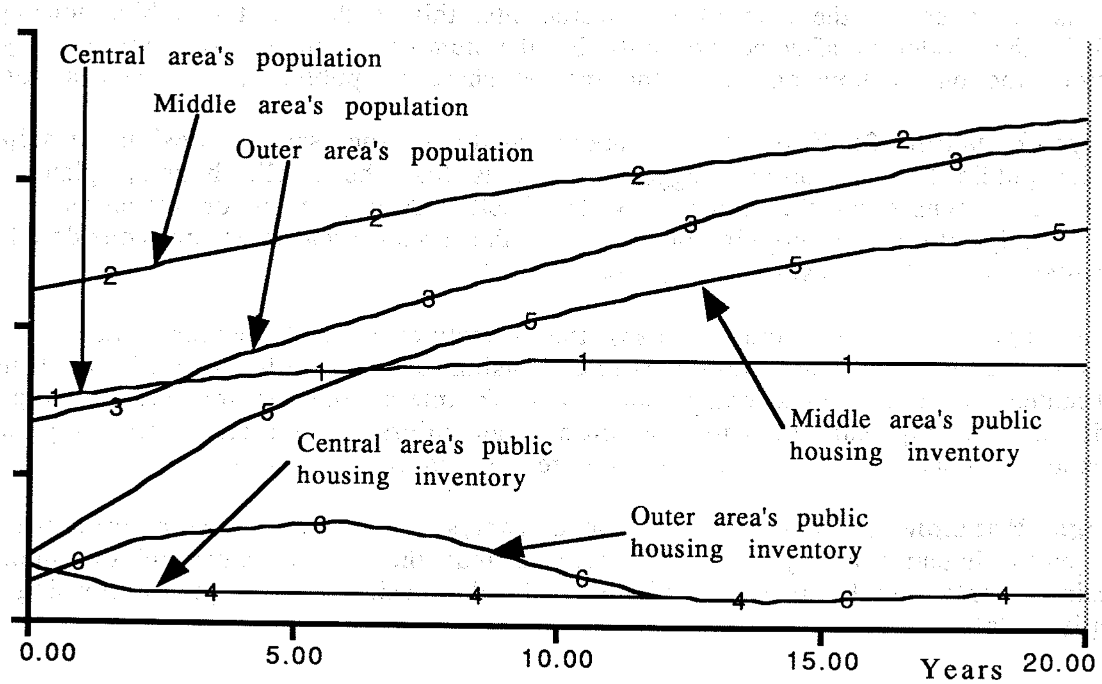

Figure 4: Population and Public Housing Inventory in Base Run

The behavioral pattern of the public housing demand is similar to the pattern of the population, because the housing need is primarily determined by the population. The housing demand is formulated as the product of housing need and the realization fraction. Thus, the determination of the location of public houses in the next twenty years should not design according to past data only. The nonlinear factors, e.g., the limitation of the environmental capacity, the traffic capacity, and the land capacity, which were not statistical significance while used the linear approach with the past data but will dominate the behaviors of the population and the public housing demand in the future. Those nonlinear factors should be considered in the design of public housing policy. Figure 4 also shows the behaviors of the public housing inventory in the base run. Those behaviors will be discussed in the section of Demonstration of Policy Design.

Design Principle 1: Through the above analysis, the first design principle of the public housing policy suggested here is that the policy should not only consider those factors which are statistical significance in the past, but also need to consider those nonlinear factors which dominate the behaviors in the future.

The Waterbed Phenomenon

The estimation of population is one of the most important issues in physical or strategic urban planning. However, the behavior of population flow among various zones is somewhat like a "waterbed phenomenon", that is, the population increase in one zone comes from the population decreases in the other zones. For example, if the city government expands the public expenditure in one zone, its increased attractiveness leads to the increase of its population, which then, through the economic mechanism, then results in more private investment, and consequently attracts more population and investment until the negative loops dominate the behaviors (see Figure 3). Figure 5 illustrates some of the simulation results of this kind of "waterbed phenomenon". In Figure 5, the increment of public housing demand is not equal to the sum of the decrements, this is due to the public housing demand in the model is affected not only by the number of population, but also by the realization fraction of housing need, the market share of public houses, and so on.

Design Principle 2: Through the above analysis, the second design principle of the public housing policy suggested here is that the public housing plan should not focuses on the housing system itself. Any policies or scenarios significantly affect the population flows in the urban area must be considered to formulate a public housing policy set.

The supply of public houses raises the attractiveness and increases the population afterwards. Thus, future public housing demand will be different from the estimated demand. This complicate feedback interactions among the housing demand, the housing supply, and the intra-urban migration structure are very often overlooked in many planning efforts and require more attentions.

Design Principle 3: Through the above analysis, the third design principle of the public housing policy suggested here is that the consequences of the public housing supply should also be considered in the design of the public housing supply itself.

Demonstration of Policy Design

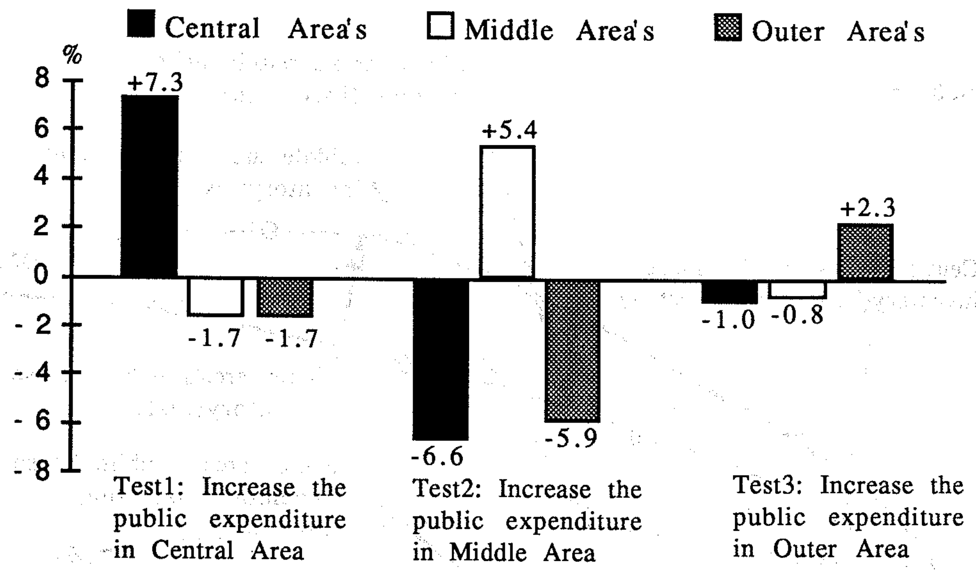

Figure 5: The Simulation Results of the Shifts among Zonal Public Housing Demands Resulted from Expanding Public Expenditure in a Specific Area

In the model, the supply of public houses is treated as one policy issue, while the supply of private houses is determined by the housing demand. As mentioned before, the effectiveness of public housing policy is evaluated by the adequate level of public housing inventory, since too much inventory leads to high inventory cost, onthe other hand, too little inventory results in unsatisfied public housing demand. Since, the inventory level is directly determined by the supply and demand of the public houses, varying the supply amount or other supply factors, e.g., the size of public houses, will change the inventory level and the demand through the consequences of the intra-urban migration structure. By testing different supply levels, the model shows the potential for decision makers to obtain some "dynamic optimal" amount of supply under various scenarios.

Figure 6 shows that increasing the amount of public houses of the Outer Area (from 900 housing unit per year to 1500 housing unit per year) and decreasing it of the Middle Area (from 1000 housing unit per year to 500 housing unit per year) result in the increment of the Outer Area's public housing inventory level and the decrement of the Middle Area's inventory level.

Figure 7 shows that by enlarging the size of public houses and varying the supply amount (Outer Area's amount is from 900 to 1500; Middle Area's from 1000 to 800; Central Area's remain 100), the increment of the Outer Area's inventory level is less than that in Figure 6, and the decrement of Middle Area's inventory level is less than that in Figure 6.

The tests in Figure 6 and Figure 7 are only some demonstrations. However, they show us the potential of the model to aid the formulation of a "dynamic" public housing policy design, that is, when to supply how much of a certain level public houses to which area of the city under a specific scenario.

4. Summary and Discussion

By focusing on the structure of intra-urban migration, it is found that the intra-urban system has a very dynamic feature. This study provides a better understanding about the complex dynamic interactions among the population flow and attractiveness within the city of Kaohsiung. The simulation results show that the

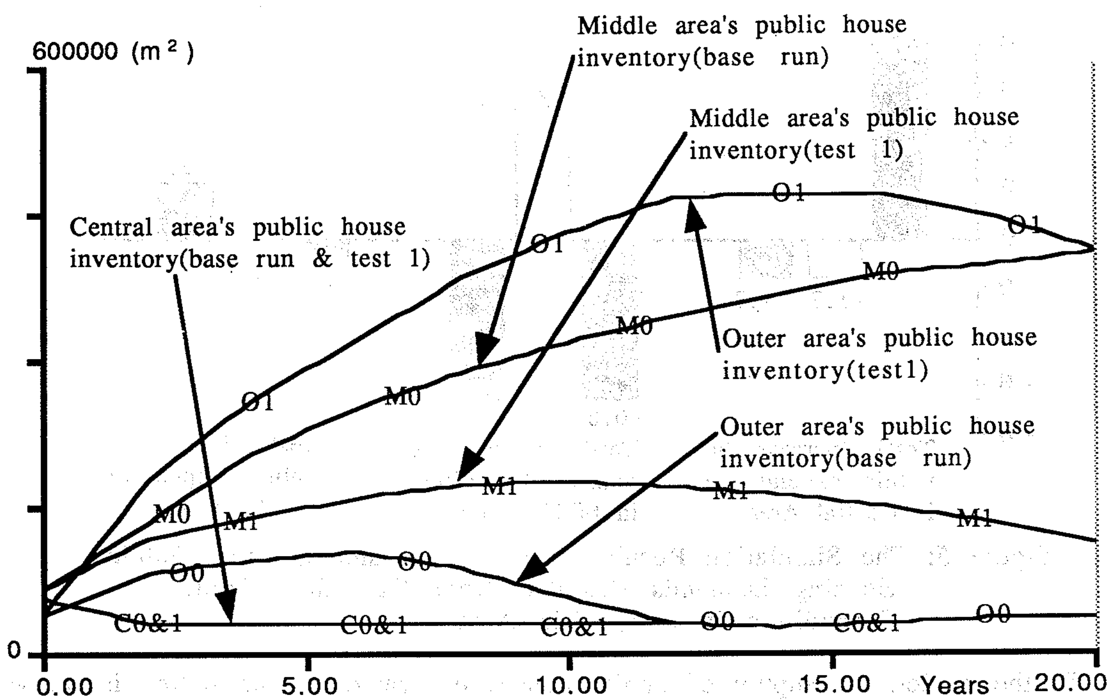

Figure 6: Demonstration of Policy Design of Test 1: Increase Outer Area Supply (from 900 to 1500) and Decrease Middle Area Supply (from 1000 to 500)

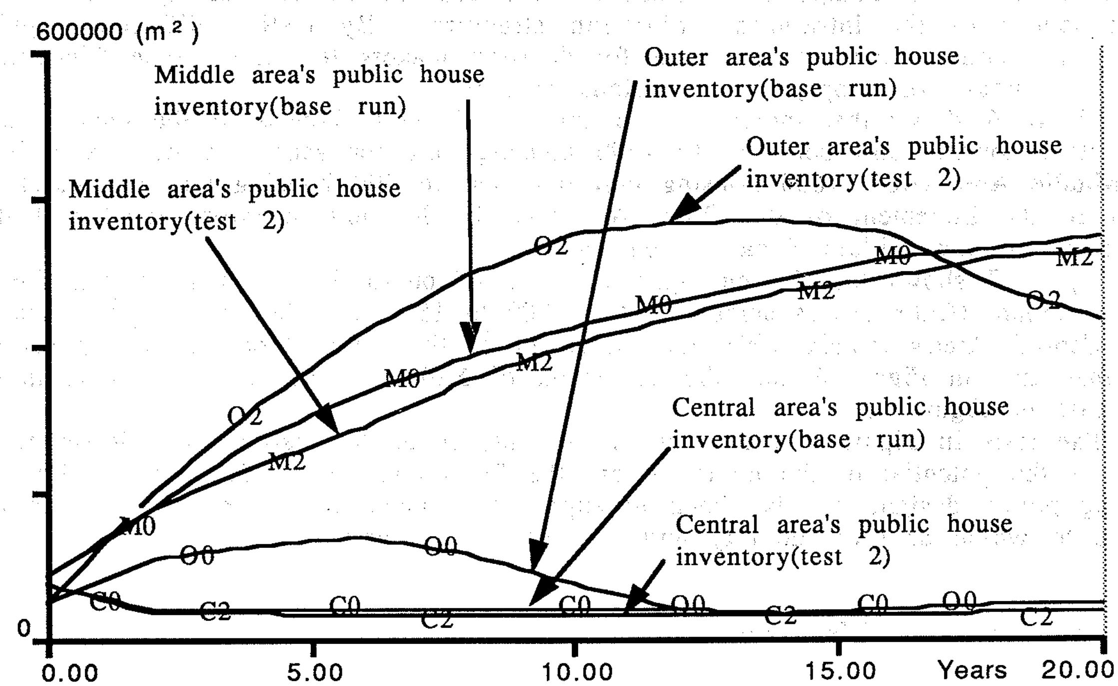

Figure 7: Demonstration of Policy Design of Test 2: Enlarge the Size of Public Houses, Increase Outer Area Supply (from 900 to 1500) , and Decrease Middle Area Supply (from 1000 to 800)

behavior of the population flow is dominated by several feedback loops, some reinforce the growth of population, while others limit it. Moreover, the population flow between different areas make the problem more complicated. It is somewhat like a "waterbed phenomenon", that is, the population increase in one zone comes from the population decreases in the other zones.

In addition, through analyzing the simulation results of the model, some design principles of the public housing policy are suggested: (1) the policy should not only consider those factors which are statistical significance in the past, but also need to consider those nonlinear factors which dominate the behaviors in the future, (2) the public housing plan should not focuses on the housing system itself, any other related policies or scenarios significantly affect the population flows in the urban area must be considered to formulate a public housing policy set, and (3) the consequences of the public housing supply should also be considered in the design of the public housing supply itself.

From the demonstration of some policy tests, it shows us the potential of the model to aid the formulation of a "dynamic" public housing policy design, that is, when to supply how much of a certain level public houses to which area of the city under a specific scenario.

This research is a preliminary attempt to employ the system dynamics approach to study the housing aspect of the spatial distribution of urban landuse activities. It still needs many further research efforts such as: considering the functional dimension of the zonal classification with the inclusion of more detailed socioeconomic status. However, at this stage, this research shows us that system dynamics is not only a useful tool to have insights into this kind of complex socioeconomic problems, but also has the potential to deal with the spatial dimension of urban issues in addition to its mostly temporal applications.

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