TOWARDS INTEGRATED URBAN MODELS FOR DEVELOPING COUNTRIES: MODELING HOUSEHOLDS AND LOCATION CHOICES USING SPATIAL MICROSIMULATION APPROACH

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Abstract: The development of urban models has been prompted by the need for informed policy recommendations from urban planners and informed decisions by policymakers. While continuous development and application has been pursued extensively in advanced countries, there have been little efforts in the developing regions of the world. This is mainly due to serious data limitations and the presence of complex modeling issues. The imperative to develop integrated urban models for developing countries is growing with the need to estimate future urban growth and forecast possible impacts of various urban policies. The study pursues the development of integrated urban models for developing countries by tackling key urban issues and modeling constraints. This paper presents the on-going development of a spatial microsimulation model for Metro Manila which provides a powerful and flexible approach for overcoming data and modeling problems. Finally, this paper presents extensions to model location choices of households under a spatial microsimulation framework.

Key Words: urban model, developing countries, microsimulation, location choice

1. INTRODUCTION

The development of urban models has been prompted by the need for informed policy recommendations from urban planners and informed decisions by policymakers. While continuous development and application have been pursued extensively in advanced countries, there has been little effort in developing countries. This is partly due to the serious limitations in data availability that severely constrain the kind of modeling work which can be pursued for cities in developing countries. If available, existing data sets may not possess the desired spatial and temporal coverage to allow more detailed and sophisticated analyses. The lag in urban modeling work for developing countries may also be due to serious difficulties in capturing the complex inter-relationships among factors in the urban system. Needless to say, the direct transfer of models from advanced countries to developing ones is no longer tenable.

There are major considerations and serious constraints that need to be tackled. However, the imperative to develop urban policy tools for planners and policy-makers in large metropolitan areas in developing countries is growing. Firstly, there is an urgent need to estimate and forecast future urban growth, land use changes, and patterns of urban travel. There is also a need to forecast the possible impacts of urban policies that pursue various development and environmental objectives.

This study discusses the various modeling issues that are critical in the development of urban models for developing countries. One critical issue is the presence of informal markets within the land, labor and transport sub-sectors of the urban system. Existing urban models incorporate market-clearing mechanisms in the allocation of land use activities under the assumption of perfectly competitive markets. However, such a framework cannot possibly capture the existing conditions in developing countries. This paper presents the spatial microsimulation approach for modeling households and location choices in developing countries. Microsimulation methodologies have become accepted tools in the evaluation of economic and social policy, and provides a very powerful platform for integrated land use, transport and environment modeling in developing countries.

2. URBAN MODELING IN DEVELOPING COUNTRIES

2.1 Historical Development of Urban Models

In western economies where urban modeling has matured, urban planners and policymakers have been constrained in the mindset that *everything affects everything else* in the city and have thus raised expectations of what models can and need to do. With the need that every public decision has to be an informed one, models were made to help policymakers understand the underlying determinants of spatial location within a city, analyze the causes of city growth and decay, and predict future land uses. While the capabilities of these models have grown by leaps and bounds due to rapid advancements in computer technologies, as well as, in the supporting mathematical techniques in the economic and social sciences, the over-reliance on such models have often led to disappointments.

In the field of economics, macroeconomic models have advanced the most. Particularly in the 1960s, we saw the development of a number of large-scale macroeconomic models that attempted to model the whole economy. The models were usually comprised of a number of sub-models, each of which was carefully developed and econometrically estimated. However, a problem was often encountered when these sub-models were put together and their interaction produced unexpected results. Consequently, they had to be "fine-tuned" for purposes of simulation. A common experience is that these models tracked the system well in the short term but performed poorly in the longer term. The key problem, in these models was the difficulty in tracing chains of causation.

In the context of urban systems, the demand for models is particularly great because of the large number of variables and available policy parameters, the complex relationships among them, and the long-term consequences of public decisions. Planners, therefore, need models for the purposes of prediction and projection, impact analyses of alternative strategies, plan design, educating planners, and controlling and directing urban change. On the other hand, the problems of multiple causality and complexity in the urban system are still the main stumbling blocks on the usefulness of such models.

2.2 Current State of Operational Urban Models

Wegener (1994) reviewed the state of the art of operational urban models. He reports that after two decades following Lee's "Requiem for Large-Scale Models" the urban modeling field is active again. There exist more than a dozen operational urban models in the world with varying levels of comprehensiveness and sophistication. With the rapid advancement of computer technologies and mathematical techniques, computations are being implemented at unprecedented speeds and complexities. The recent resurgence of urban modeling activities worldwide is prompted by the urgency of the environmental debate and the need to provide models capable of estimating energy usage and environmental damage. Figure 1 shows the map of active modeling research centers in the world in the late 1980s and early 1990s. It is important to note that there is indeed little work in modeling cities in developing countries.

Wegener (1994) reports that urban models in the past have been applied to a very narrow set of planning problems, and have failed to adapt to changing perceptions of the problem. Models should be made more sensitive to issues of equity and of environmental sustainability. Particularly, models incorporating socio-economic distributions are expected to play a significant role in improving the present set of models. Wilson (1997) reviewed the theoretical development and applications of land-use/transport models. Urban models in existence exhibit very good reproductive capabilities (i.e. the ability to reproduce the current (or a historical) situation as represented by the data on that situation), however, there is still much more area to cover in terms of empirical work on their predictive capabilities. The 'aggregation problem' is still an issue to reckon with and calls for the integration of more detailed data sets and models that can represent the urban structure at the micro-scale.

Figure 1. Map of active urban modeling centers

While modeling of urban systems has found several successful applications in Western countries, there is still a dearth of similar activities for cities in developing countries. It is no doubt that the process of urban growth and development is more complex in developing countries.

2.3 Urban Systems in Developing Countries

The intricacies of the structure of the social organizations and individual behavior, as well as, the presence of many market imperfections, has prompted urban analysts and researchers to express caution on to the issues that need to be dealt with in making models work for developing counties.

McGee (1971) has tried to unravel the urbanization process in developing countries by comparing western theories and third world realities. He notes that while the process of urbanization in developing countries show some similar trend with its western counterparts, urbanization in the third world is happening at a compressed time-scale, greater magnitude and complex socio-economic conditions. McGee further exposed that urbanization studies in the third world should be undertaken in the broader investigation of the 'forces influencing the society and country as a whole'. Lakshmanan (1981) has reviewed the policy applications of urban development models in the United States and the implications on developing countries. He argues that the key to the development of urban models lie in the structures that promote modeler-policy maker interactions. The modeler must be in touch with the policy maker and the policy maker should understand the attributes of the models. Lakshmanan points out that it would be a mistake to make isomorphic transfers of urban development models from developed cities to the developing world. Finally, Mohan (1979) stresses the need to account for the larger public sectors and market structures in developing countries. Attention should be given to the particular institutional structure of the country concerned. Furthermore, he points out that urban models should be seen as a process rather than as products. Mohan suggests that clear and reliable information is required in areas such as transport, housing, and the informal sector in developing countries.

2.4 Modeling Issues in Developing Countries

Tiglao (2001) highlighted key modeling issues that need to be tackled in the development of urban models for developing countries citing the particular experience of Metro Manila in the Philippines. Firstly, there has been explosive population growth among cities in developing countries. The rapid growth in population is also coupled by the presence of severe economic inequality among individuals and households. The large gap between the rich and the poor is very much evident in the housing and labor sectors of the urban economy. From the viewpoint of modeling, there is a need to effectively distinguish the various income and social groups. The current modeling practice of defining 'representative households' needs to be refined in order to capture the household structure in developing countries at a disaggregated level.

A second very vital issue is the presence of large informal sector. Until recently, urban analysts have largely dismissed the existence of low-income or the so-called marginal settlements in the analysis of the urban system. More seriously, policy-makers and planers have failed to recognize at an early stage the evolution of an ever-growing informal sector in cities in developing countries. The analysis of the informal sector is severely limited by the lack of reliable data, as well as, non-existence of formal methods of measurement. The definition of the informal sector varies, however, it is generally considered to be that portion of the economy which are operating outside the formal, or established system of laws and urban structure. Table 1 shows the growth of informal settlers in Metro Manila and the magnitude is by no means trivial.

Table 1. Growth of informal settlements in Metro Manila

Year	Number of Informal Households	% of Total Households
1988	150,721	10.5
1991	192,394	11.7
1994	245,425	13.9
2000	726,908	34.2

Source: Urban Sector Profile, ADB(1999)
National Housing Authority (2000)

The previous two issues are compounded by urban primacy and high in-city migration. In developing countries a lot of people are moving to capital cities in which there are no jobs reserved for them. The surge in population drives further urban sprawl, unemployment and the expansion of the urban informal sector. The complex interplay of regional and international migration leads to a very dynamic population base.

3. MICROSIMULATION MODELING

3.1 Origin of Microsimulation Modeling

Microsimulation modeling originated in the field of economics through the pioneering work of Guy Orcutt (Merz, 1991). Microsimulation models in economic applications may be divided into static, dynamic and longitudinal types. All these model work with cross-section data. A static microsimulation model treats a fixed number of micro-units and the attributes of this same set of microunits are reweighted to account for changes in demographic structure over time. A dynamic microsimulation model ages each micro-unit individually by an empirical survival probability. The main difference between a dynamic microsimulation and a static one is the aging procedure. A static aging procedure is relatively well-suited short- and medium-range forecasts, provided it can be assumed that the characteristics of the population under examination do not change rapidly. A third type of microsimulation model found in economic literature is the dynamic longitudinal model which creates synthetic microunits and forecasts a microunit's whole lifecycle from birth to death. Thus, a dynamic microsimulation model does not forecast the characteristics of real sample units but the assigned characteristics of synthetic microunits.

3.2 Microsimulation in Regional Science

Clarke and Holm (1987) provides a through presentation on how microsimulation methods can be applied in regional science and planning analysis. Clarke (1996) points out that there are two major works involved in applying microsimulation methods in spatial analysis. The first involves the creation of a microdata set using conditional probabilities and contingency tables. A method called iterative proportional fitting is also used to create probabilities using data sets which have different spatial scale. The next step involves the creation of a sample of individuals or households based on the set of probabilities. Microsimulation methods has not received wide application in regional science due to the lack of microdata sets to calibrate or test results of simulation. This situation is changing as survey data are becoming more readily available, even for developing countries.

Figure 2 illustrates how microsimulation can be employed for the creation of a micro-level population with the population characteristics: age, sex, marital status and household tenure. Supposing that age, sex, and marital status of the household head is available from the census, it is then possible to estimate probabilities of household tenure. The first synthetic household has the following characteristics: male household head, aged 27, married. The estimated probability that a household of this type would be owner-occupied is 70. The next step in the procedure is to generate a random number to see if the synthetic household gets allocated to the owner-occupier category. The random number in this example is 0.542 which falls within the 0.001 to 0.700 range needed to quality as owner-occupied. The same procedure is then carried out sequentially for the tenure allocation of all synthetic households. It should be noted that that difficult task in microsimulation is to specify which variables are independent upon others and to determine the ordering of probabilities.

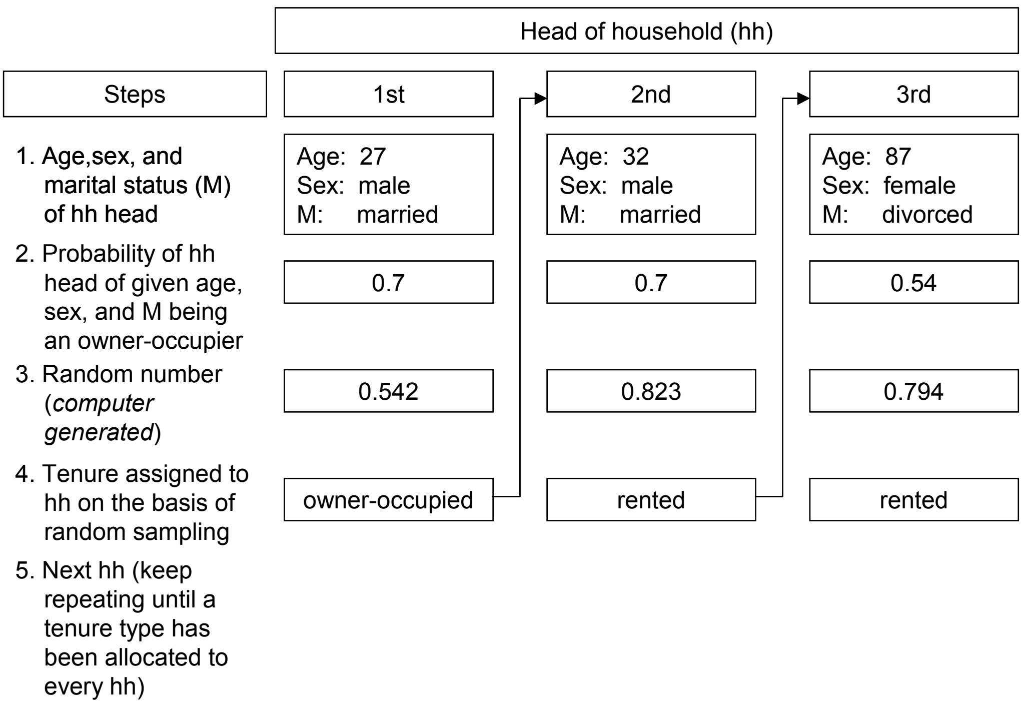

Figure 2. Example of spatial microsimulation process (Clarke, 1996)

3.3 Application of Microsimulation to Urban Modeling

There are several early applications of microsimulation to urban modeling in literature. Wegener (1985) used Monte Carlo simulation approach to model housing market of Dortmund taking into account the choice behavior of households and landlords. On the demand side, considerable effort was devoted to modeling the life cycle of households and their concurrently changing decision situations and preferences. On the supply side, the housing stock is changed through aging, public housing programs, or private construction by housing investors or owner-occupants.

Up to now, a large number of microsimulation models are inherently *aspatial*. This means that existing microsimulation models does not incorporate sufficient geographic detail so as to allow richer analysis at fine spatial levels. Microsimulation models would potentially find relevant applications to policy simulations at neighborhood levels, and even voting and school districts.

An on-going development of state-of-the-art application of microsimulation to landuse-transport modeling is the UrbanSim at the University of Washington (Waddell, 1998). The model system is implemented as a set of interacting model components that represent the major actors and choices in the urban system, including household moving and residential location, business choices of employment location, and developer choices of locations and types of real estate development, all subject to the influence of governmental transportation and land use policy scenarios. The model design is unusual in the degree of disaggregation of space, time, and agents, and in the adoption of a dynamic disequilibrium approach.

This study argues that spatial microsimulation approach provides a very powerful framework in overcoming the data and modeling problems in the development of integrated urban models for developing countries. One main advantage of the spatial microsimulation approach is that it is capable of building reliable disaggregate data sets at the household level and provide it at an appropriately fine geographic scale for detailed analysis. It is able to utilize existing disparate data sets and it is flexible enough to incorporate new available information. Finally, since household micro data can be developed, appropriate models can be calibrated and tested using the rich database.

4. SPATIAL MICROSIMULATION OF HOUSEHOLDS CHARACTERISTICS IN DEVELOPING COUNTRIES

4.1 Spatial Microsimulation of Informal Households in Metro Manila

InformalSim is the first application of spatial microsimulation approach for modeling the characteristics of households, particularly those in the informal sector (Tiglao, 2002a). Presently, InformalSim covers the City of Manila. However, the model can be easily extended to cover other cities and municipalities in Metro Manila. The City of Manila consists of 54 traffic analysis zones, 900 barangays and around 1.65 million persons in 1990. The model system consists of several modules that provide spatially-disaggregate household microdata that enables the distinction between the formal and informal households. In InformalSim, the *informal household* is characterized using two dimensions, namely, urban poverty and housing tenure. It is noted that the term *informal settler* which only refers to the tenure condition is more commonly used.

Table 1 shows the data sets used in developing the spatial microsimulation model. Each data set is available under a specified zoning system and sampling scheme. Each data were undertaken with specific purposes in mind. Since, data are very costly to obtain, there is great benefit in utilizing existing data. The challenge therefore is how to integrate disparate data and produce a richer data set that would allow the identification of informal households. The main source of household income and expenditure data is the Family Income and Expenditure Survey (FIES). The FIES has been conducted every three years since 1988. It contains very detailed information of sources of household income and expenditure, however, only for a very limited sample. The subset of the data for Metro Manila consists of about 4,030 samples. Through the FIES data, household income profiles are officially published at the city and/or municipality level. The next source of household income data is the 1996 Metro Manila Urban Transportation Integration Study (MMUTIS). The primary source of detailed socio-demographic data used in the study is the 1990 Census of Housing and Population (CPH). The CPH does not contain income-related variables. The study also utilized GIS data sets from MMUTIS. A recent spatial data set used is the building footprint for Metro Manila. The data set contains the plan projection of roof of individual dwelling units and buildings.

Table 2. Available data sets

Zone System	Data Set	Description/ Coverage
City	1997 Family Income and Expenditure Survey (FIES)	• Household demographics, some housing variables • Detailed household incomes and expenditures • 4,030 samples for Metro Manila
Traffic Zone	1996 Metro Manila Urban Transportation Integration Study (MMUTIS)	• Selected household demographics • Member/ household income • 50,000 samples for Metro Manila
Barangay	1990 Census of Population and Housing (CPH)	• Detailed household and housing characteristics • No income/employment variable • Non-response on housing variables • All households in 1990 (1,567,665 households)
GIS	1996 MMUTIS Land Use GIS 1997 Building Footprint Data	• Urban land use zoning map for entire Metro Manila • Building footprints for most cities

Figure 3 shows the simulation process of InformalSim. The object of the microsimulation is to estimate characteristics of households in the microdata that would allow identification of informal households. First, a baseline population consisting of all households in the 1990 CPH is initialized. Then, the economic activity of household head is estimated using conditional probabilities from the 1996 MMUTIS data. The MMUTIS, or Metro Manila Urban Transportation Integration Study, is a transportation planning project undertaken from 1996 to 1999 which had assembled detailed household and member characteristics for 2.5 of the total number of households in Metro Manila. The characteristics include household income and employment information of the household head. Assignments of economic activity are done using Monte Carlo sampling based on the characteristics of the household head, namely, sex, age, and location. Next, occupation and employment sector probabilities are computed and assignments are done using Monte Carlo sampling. The occupation and employment sector probabilities are estimated using multinomial logit models which are calibrated using the 1997 FIES data set. The FIES, or Family Income and Expenditure Survey, is undertaken every 3 years for a small number of households nationwide. In 1997, the sample size is 40,000 household which is taken to be representative only at the city or municipality level.

The next stage involves the estimation of household incomes based on the characteristics of the household head. To achieve this, the employment status of the household head is first determined. The employment status of the household is estimated using a probit model, that is, a binary choice model of being a wage earner (i.e. formal sector) or self-employed (i.e. informal sector). Then, conditional on employment status, the household income is computed using a regression model with correction for selectivity in the lines of Lee (1978). Then, the permanent income of the household is estimated. Permanent income is needed to estimate the imputed housing value. Housing values are estimated using in two steps. First, housing tenure choice is estimated using a probit model of whether the household is under formal or informal housing. Formal housing consists of owner-occupiers and renters. On the other hand, informal housing are attributed to households who own the house but rents (with or without consent of owner) the land. Then, housing value is computed using a regression model conditional on the tenure status with the appropriate correction for selectivity bias in the lines of Lee and Trost (1978). Simulated values can then be visualized using GIS and the output can be analyzed in a 'complete-data' setting.

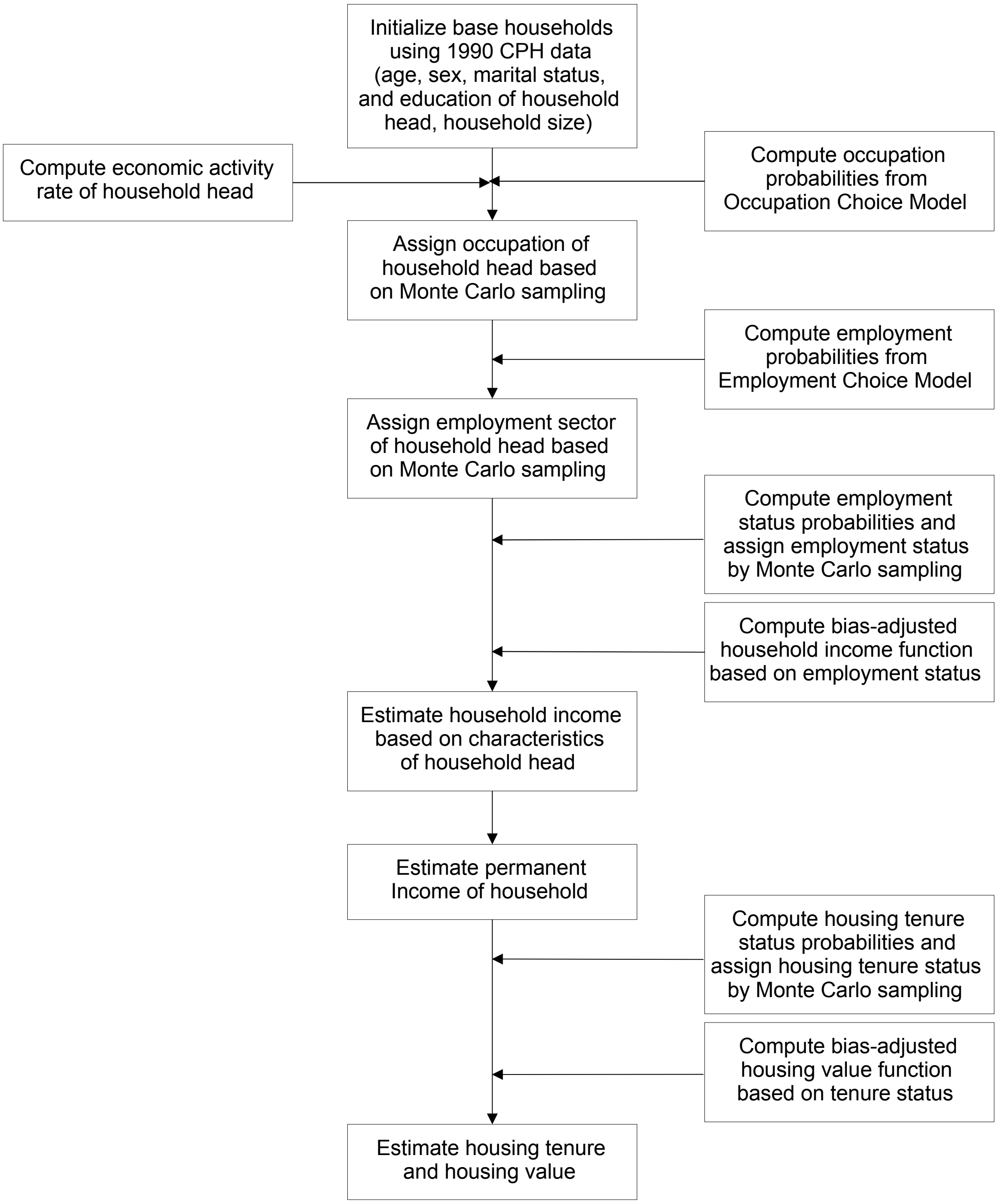

Figure 3. Spatial microsimulation of informal households

Figure 4 presents the object representation of household microdata. The object-oriented approach to spatial microsimulation modeling was proposed by Ballas et al. (1999). Object-oriented programming offers a very flexible platform for estimation and handling of very large data sets. InformalSim is implemented in *Java*. There are two major objects in InformalSim, namely, the member object and the household object. These two objects contain variables and methods. Variables correspond to the actual characteristics of the respective objects. Variables are of two types-baseline (i.e. observed) and unobserved. Methods contain computational codes or models that operate on the variables. Each household object contains a vector (or collection) of member objects as would be true in the physical sense. This representation is completely convenient as the characteristics of the household are entirely dependent on the members that comprise it. Moreover, the approach allows limitless flexibility as future implementations may be conveniently incorporated into the structure.

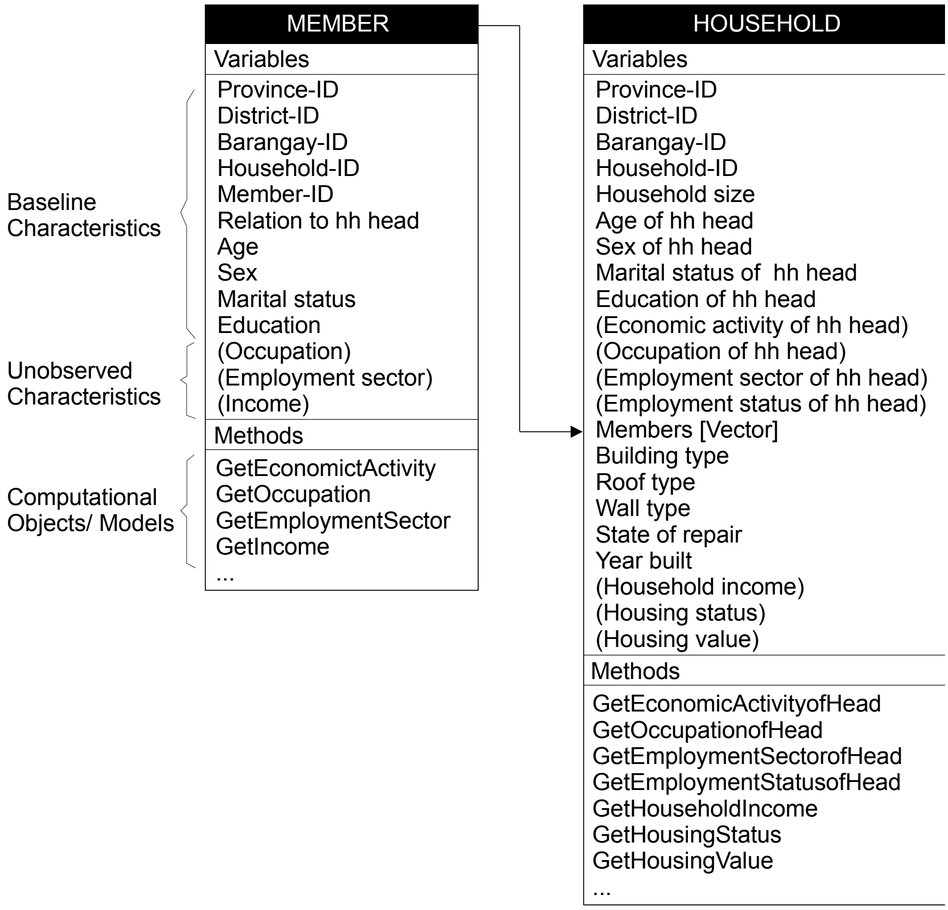

Figure 4. Object representation of household microdata

4.2 Calibration of Spatial Microsimulation Model

The current implementation of InformalSim consists of 10 modules. Each of the modules are calibrated econometric models, either in the form of Ordinary Least Squares (OLS) regressions models or Limited-Dependent models that incorporate sample selection. The modules are as follows:

1) Economic Activity Module

Economic activity rates are computed as conditional probability of an individual being economically active given age, sex and location using the 1996 MMUTIS data. MMUTIS contains employment data of household heads with a 2.5 percent sampling for each of the traffic analysis zone. The estimated rates for each zone are applied to all households in the barangays that are located with each particular zone.

The assignment of whether a particular household head or member is economically active or not is determined using Monte Carlo sampling. The process involves drawings of random numbers and comparing it with the conditional probabilities.

2) Occupational Choice Module

The occupational choice is formulated as a multinomial logit model with the actual occupation type as observed choices of the household head. The model includes education level and age (proxy for experience) as explanatory variables. Separate models are estimated for male and female household heads. There are seven occupation groups, namely: Professional, Administrative, Clerical, Sales, Services, Agriculture, and Production.

3) Employment Sector Choice Module

The employment sector choice is also formulated as a multinomial logit model. It includes education level and age as explanatory variables for observed employment sector. Similarly, separate models are estimated for male and female household heads. There are six employment sectors, namely: Agriculture, Manufacturing, Wholesale & Retail, Transportation, Financing, and Community Services.

4) Employment Status Module

The employment status sub-model determines whether the household head works in the formal or informal sector. The household head works in the formal sector when he/she is employed by a firm, whether government or in the private sector. On the other hand, a household head who is self-employed or works for another household is considered to be in the informal sector. Employment status is formulated as a probit model with the following explanatory variables: sex, age, age squared, marital status, education level, household size, occupation type, and employment sector. This model provides a reduced-form probit equation in a three-stage model of household income with selectivity on employment status.

5) Household Income Module

The household income sub-model estimates the household income for a household head and taking into account the employment status of that particular head. Rather than simply calibrating regression models by ordinary least squares (OLS), the household income models incorporate bias corrections for selectivity. Separate household income functions were estimated for the formal and informal sector. Moreover, correction terms were found to be statistically different from zero.

6) Permanent Income Module

The permanent income sub-model estimates the permanent income of the household given human and non-human wealth characteristics of the household. The explanatory variables include age, age squared, education level, education level squared, household type, and household income.

7) Housing Tenure Module

The housing tenure sub-model determines whether the household belongs to the formal or informal housing. Formal tenure consists of owners, renters, and those who own land while informal tenure refers to those who may own house but does not own the land. Housing tenure status is formulated as a probit model with the following explanatory variables: education level of household head, household size, and permanent income. This model provides a reduced-form probit equation in a three-stage model of housing value with selectivity on housing tenure status.

8) Housing Value Module

The housing value sub-model estimates the imputed value of housing for each incorporates bias corrections for selectivity on housing tenure status. household. Separate housing value functions were estimated for the formal and informal housing tenures. Correction terms were found to be statistically different from zero.

9) Inequality Measures Module

The module takes the full array of incomes in the household microdata and generates three measures of inequality, namely: Gini coefficient, Theil index, and Coefficient of Variation (CV). It is possible to incorporate other measures on inequality based on human capital.

10) Mapping and Visualization Module

The mapping and visualization module provides the graphical interface for the internal data in the modeling system.

4.3 Simulation Results and Validation

Figures 5 and 6 show examples of output of the microsimulation. Figure 6 shows the mean household incomes per zone. Figure 6 shows the percentage of informal employment per zone.

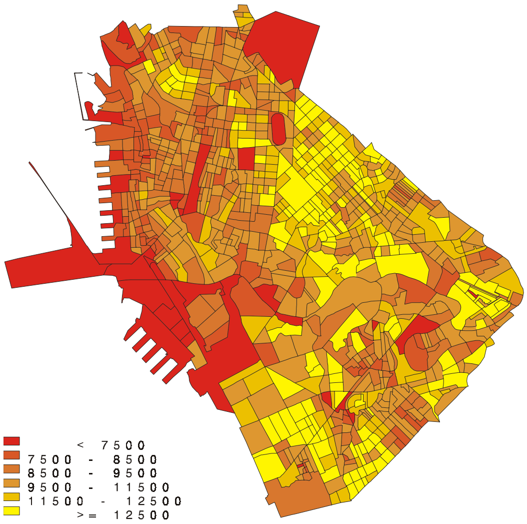

Figure 5. Simulated mean household incomes

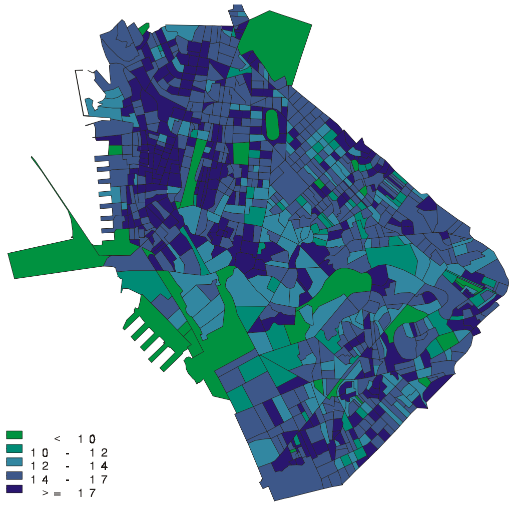

Figure 6. Simulated informal employment (% of households)

Figure 7 shows the validation process of the simulation results. The validation process generally involves the establishment of reliable estimates of parameters of interest using small area estimation techniques. These reliable estimates provide benchmark values at the appropriate scale that can be used to compare with simulated values. In the case household incomes, survey data are only available at the traffic zone level. Small area estimation allow for more reliable estimates since it incorporates the use of auxiliary variables to estimate mean incomes for each traffic zone. The resulting benchmark values are then compared with aggregated values from the simulation. Figure 8 shows the comparison of simulated and true values. It can be observed that there is very good agreement between the two. Estimates of informal employment are more difficult to validate since census-based information suffer from non-response and there are no existing formal surveys to capture informal employment.

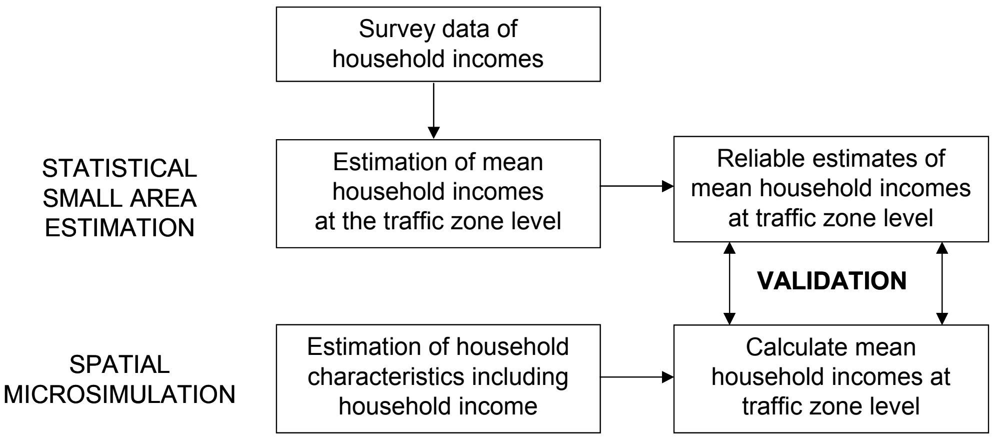

Figure 7. Validation of spatial microsimulation output

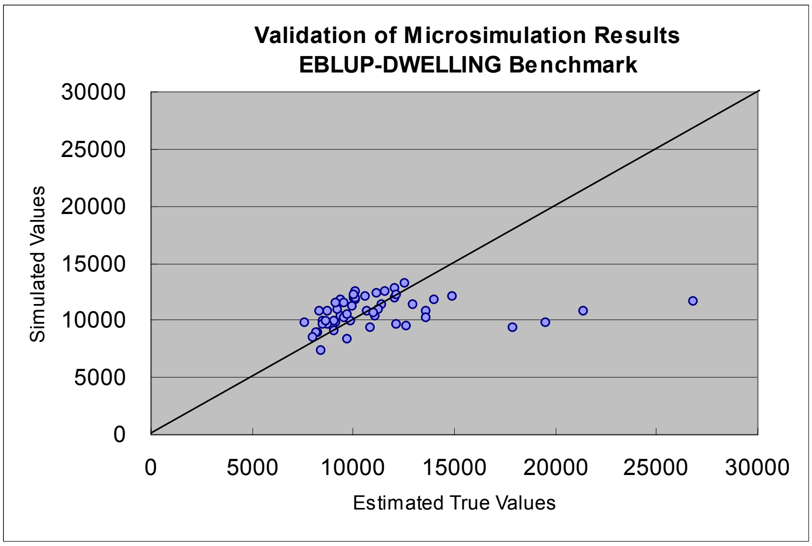

Figure 8. Comparison of simulated and true values

Further validation work can be done mainly requiring ground-truth activities and actual conduct of sampling surveys. An alternative way would be to use common knowledge of the area. Figure 9 shows the map of mean household incomes and aerial photographs of the areas in Manila where there are perceived to be dominance of low-income households and informal households. Qualitative comparison and checking of simulated values can be done.

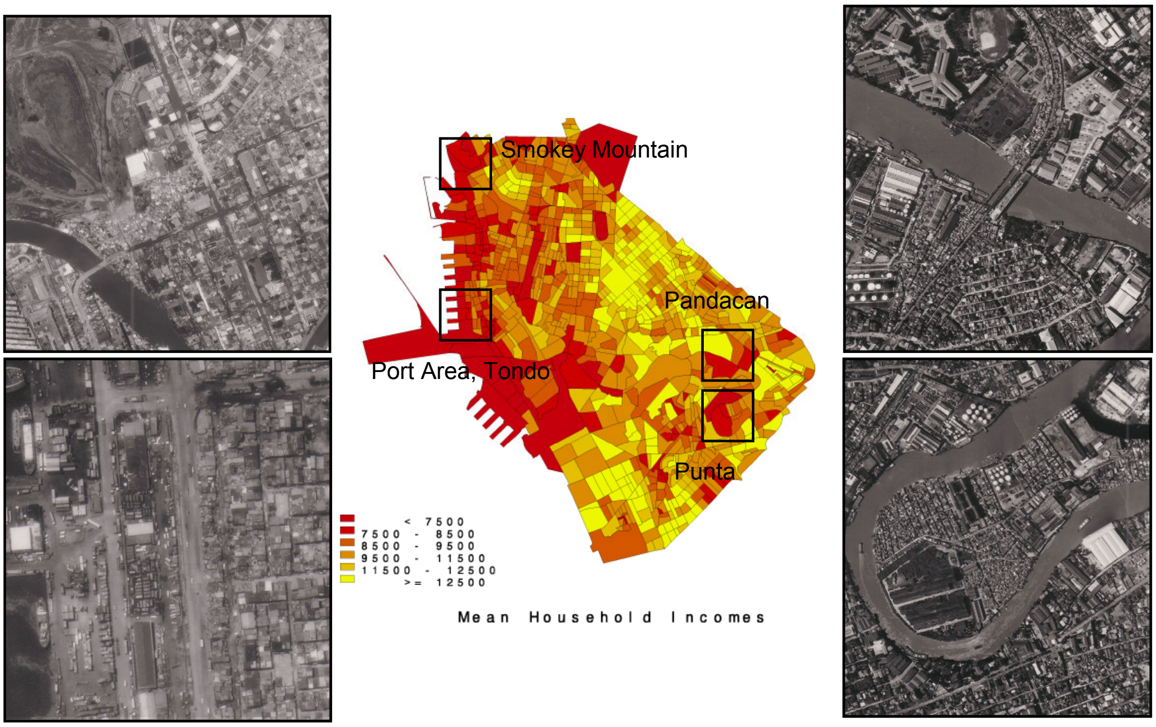

Figure 9. Mean household incomes and

5. MODELING HOUSEHOLD LOCATION CHOICES

5.1 Possible Specification of Location Choice Model

The full-scale application of spatial microsimulation approach to urban modeling is very recent. One work in this area is the UrbanSim model being developed at the University of Washington. UrbanSim incorporates an innovative approach for modeling location choices of households. Here we review their approach and clarify issues for the incorporation of such similar functionality into InformalSim.

Firstly, it is noted that the general approach in the development of UrbanSim is very much similar with the modeling framework adopted in this paper. Even though InformalSim is a very recent effort, its similarities with UrbanSim are striking considering that InformalSim was developed without the clear knowledge of the existence of UrbanSim and its structure. Nonetheless, the approach and theoretical underpinnings of UrbanSim holds great potential for InformalSim.

The market allocation mechanism in UrbanSim which is used to assign household and jobs to available space is not done through a general equilibrium solution in which consumers and suppliers optimize across all alternatives based on perfect information, and zero transaction costs. Such an equilibrium framework requires that prices on all buildings at each location adjust to the general equilibrium solution that perfectly matches consumers and suppliers to clear the market. Rather, the solution is based on an expectation of incomplete information and nontrivial transaction and search costs.

Using the general approach of UrbanSim, the household location choice model may be specified as a multinomial logit model with the following explanatory variables:

- household income
- neighborhood quality
- accessibility to workplace
- social network

Household income and neighborhood quality is already directly captured in the existing modules of InformalSim. Accessibility to workplace requires the identification and development of accessibility measures. Accessibility measures can be calculated using level of activities per zone (e.g. number of employees, daily number of trips). Moreover, GIS can provide a framework for the development of accessibility measures. Social network variables can also be captured by the use of inequality measures with the hypothesis that more equal neighborhoods provide an environment for better social connectedness among households. It is noted that the current version of InformalSim already provides measures of inequality.

5.2 Location Choices of Informal Households

Tiglao and Tsutsumi (2001) present a preliminary analysis on the spatial distribution of low-income households in Metro Manila. The study suggests that the magnitude of low-income households is explained by population, density and land-use variables. It is interesting to note that population density provides a strong significant explanatory variable for the number of low-income households in each zone. While this point may not be readily supported by available aggregate data and is truly contingent on local land use conditions, it can be observed that informal settlements do exhibit dense and compact configurations. In relation to land use characteristics that influence location of informal households, the study points out that such households are likely to locate in undeveloped or uninhabited areas, as well as, areas with institutional uses. Present statistics support this as majority of informal settlers are located in open and Government-owned areas.

6. FURTHER RESEARCH WORK

The imperative to develop urban models and policy tools for developing countries is growing. On the other hand, there are serious constraints and modeling issues that need to be tackled if modeling work in developing countries is to be pursued. Spatial microsimulation provides a very flexible and powerful platform for modeling cities in developing countries.

InformalSim is a spatial microsimulation model for Metro Manila. It provides household microdata by integrating available survey and census-based data. The resulting household microdata possesses more detailed attribute and spatial detail. The estimation of household incomes and housing tenure characteristics will enable analysts to distinguish between formal and informal households. Additional modules and extensions can be added into the model system. Particularly, residential location choice models may provide powerful extensions towards the development of integrated urban models for developing countries. It is envisioned that spatial microsimulation will become an indispensable tool in policy analysis and urban modeling for cities in developing countries.

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