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A Study on Model Reference Adaptive Control in Economic Development (IX) — Model Reference Adaptive Housing Model —

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Abstract

One of the most serious consequences of the current Spate of rapid population growth taking place in most third world countries is the great headache imposed on development planners as they grapple with problems associated with the provision of adequate and safe shelter for this teeming population. The investment outlay associated with such a task is enormous and perhaps unattainable in the foreseeable future, calling for careful utilization of the scanty resources available to minimize the effects of this problem.

The study below, explores some of the potential ways for meeting future housing investment requirements in Kumasi city in Ghana (Africa) against a background of anticipated future housing stock and investment deficiencies among the city's existing socio - economic groups. For this purpose, we introduce a model based on the Model Reference Adaptive control system, an analytical framework which has been widely employed in the spheres of production engineering and economic development. This study, however, illustrates one of the pioneering attempts to apply this framework for the analysis of housing sector policy.

Key Words : Model Reference Adaptive Control System, Model Reference Adaptive Housing Model, Socio - Economic Groups, Third World, Policy Options, Social Security Fund,

1. Introduction

Ever since the second world war, urbanism has rapidly become a way of life in the world. In a recent study conducted under the auspices of the United Nations (UN), it was revealed that there are likely to be 24 cities with over 10 million inhabitants in the year 2000 and that about two thirds of the world's population would live in urban centres (16). This statistics reflect the rapid, and sometimes accelerating pace of the world's urbanization process.

Initially, urbanization started in the western European nations due to the Industrial Revolution and likewise, there were pre - industrial urban centers in the third world. But the situation is changing and developing nations are acquiring an expanding share of the world's population.

However, the process of urbanization in the cities in the developing world is character-

ised by mass rural to urban migration and the extensive concentration of economic activities in these urban centers. This spatial phenomenon, due largely to the failure of most of the post - independence era development plans particularly in African countries to bridge the socio - economic disparities existing between rural and urban areas has resulted in an unparalleled stream of migration of able - bodied rural dwellers into the urban centers in recent years. The result is that the population size of most African cities are expected to quadruple before the end of the present century (16).

But under the illusion of favourable job opportunities and higher standards of living, these migrants have come to constitute one of the greatest sources of developmental menace in the urban areas of the third world. With the low skills that they possess, their access to the job market is restricted to the informal and menial sectors where remuneration are low and unreliable. This situation reduces their affordability levels for basic services to levels that are exceedingly low and chaotic. To ensure survival and sustenance in this 'alien' system, these migrants resort to unorthodox, makeshift and often rudimentary approaches mostly at variance with the legally accepted regulations for the maintenance of clear, safe and liveable urban environments.

Without doubt, however, the most significant impact of the above phenomenon and the most visible aspects of the concentration of poverty in cities has been felt in the housing sector of third world cities with the result that a significant proportion of housing in most third world cities are unacceptable in terms of existing local regulations. Sprawling squatter settlements, unserved by water and sanitation and subject to fire, floods and epidemics, have come to symbolize urban conditions of the third world, despite more than two decades of attention to these problem.

The need to revolutionize housing construction activities in the third world as a fundamental step towards the general improvement of the urban environment has received varying responses and thus the level of successes and failures are equally varying among nations and cities. In recent years, however, the general contention has been that the solutions to these problems are not being generated anywhere commensurate with the problems at hand. The present pace of urban population growth and profound poverty being experienced by most third world cities makes it imperative that radical counter-measures need to be evolved.

To confront these expatiated housing problems, call for an urgent need for policy makers to expend more efforts to get a complete and realistic definition of the task at hand. Previous attempts at redressing these problems seemed to have suffered from serious setbacks embodied in the lack of coherent and self - sustaining policies to accommodate long - term and uninterrupted housing development activities. For example, a clearer understanding of housing investment activities of the different socio - economic groups in a particular housing market could act as a fundamental basis upon which housing strategies could be formulated. In this way, the disadvantaged or highly vulnerable groups can be catered for in terms of policies that can augment their affordability levels for housing consumption. This is the central theme of this research and it is meant to develop a methodological framework for the examination of different investment options that can be made available to the different socio - economic groups within Kumasi city in Ghana. This

city depicts traits of mass in - migration and its attendant housing problems have been aggravating in recent years. The methodological framework as developed for this study is based on the modification of the Model reference adaptive control framework as applied in the analysis of production engineering and macro-economic development problems.

The rest of the paper examines the following in this order :

First, for a clear understanding of the city's present housing conditions, a review is made of the up - to - date housing policies in the country as pursued by the centralised housing planning Ministry of the country and the various commissions set up to undertake such a task and in addition, an overview of the present housing conditions within the city is also presented.

Next, the methodological framework for the analysis of the city's housing investment options based on the Model reference adaptive (MRAS) framework is presented and analysed in the subsequent section.

The next section illustrates the model performance while the final section presents the conclusions and the directions for future research.

2. Over-view of Housing Policies in Ghana

Housing policies pursued to date in Ghana have followed closely those pursued in other countries in the developing world. The section below discusses these policies under four political eras associated with the country's history.

2.1 Pre-independence Era

Housing policies in the pre-independence era were similar to those elsewhere in British Africa. They were carried out under a policy objective of (a) stabilizing the urban population, (b) improving health and hygiene in the low income housing areas that were inhabited by the natives. The persistency of housing problems at that time led to the establishment of a three-man United Nations commission in 1956 (a year before the attainment of political independence) to lay a solid foundation for future housing policy making (9). The commission's recommendations were among others, the following :

- (a) Land tenure reform and the use of compulsory purchase to obtain land for housing.
- (b) Flexible financial policies to suit low income households and as adjunct, the formation of a building society.
- (c) Encouragement of self-help through roof loans in both urban and rural areas, and the improvement of existing urban housing.
- (d) Subsidized housing for low income groups.
- (e) Middle income earners to rent or buy government initiated housing at economic rates.
- (f) Encouragement of indigenous styles and technology.

However, because of the limited time span that existed between the end of the commission's work and independence which automatically led to a change in government, not much was achieved in the direction of the implementation of these recommendations.

It however led to the establishment of the state housing corporation, a building society, a roof loans scheme in the rural areas, a new town and country planning act as well as a land registration act.

2.2 Immediate Post Independence Era (1957–1966) Despite the inclusion of the doctrine of self-help in the major development plan after independence (1959) and site and service approach in the seven-year development plan of 1964 as the only practical way for low income groups to build for themselves with technical assistance, no major attempt was made to establish an effective machinery towards the realization of these stated objectives. Instead, financial system was set up to aid the creditworthy (who were inevitably the affordable class) to own their own houses. The government also became directly involved through the State housing corporation (SHC) and the Tema development corporation (TDC) to build houses for subsidized rental or outright sale. The SHC housing construction activities were concentrated in regional capitals and some important urban centres especially the mining towns, perhaps as a political strategy to attract votes from the vocal urban dwellers. However, these housing services could only be patronised by the well-offs because of their high purchasing price.

2.3 The 1966–1981 Era

This era exemplifies the one in which national housing policies became very volatile because of rampant changes in government. The National liberation council (NLC) and the Busia regimes were in power for a period totalling six years. It is therefore very difficult to provide a viable assessment of their intended policies because they hardly had any ramifications on the housing sector before their subsequent replacements.

The NRC government which took over power in 1972 evolved a pragmatic low cost housing policy that succeeded briefly in boosting the national housing stock by 6500 but whether it served its target group is highly debatable as the houses constructed under this policy directive was something beyond the means of the low income earner (9).

The Supreme military council (SMC), which was the follow up to the NRC, instituted a commission – the Nartey commission in 1976 to delve into the same issue of offering sound policy proposals to help ameliorate housing problems facing the poor. However, the commission's report flawed on issues such as the generosity of the space requirements per dwelling and the service requirements. Without doubt, they were too high and prohibitive for their intended occupiers. In addition, it also flawed on its inability to recommend a suitable machinery for the realization of these policy objectives (9).

The next government, the Rawlings era, which was shortlived, introduced some far reaching radical policies in the form of decrees. For example, rent control decrees were established and rigidly enforced only to be relaxed by the incoming civilian administration which slipped into oblivion like those experienced in the pre-Rawlings era. The effort of this civilian administration to secure a World bank loan to aid housing construction could not materialise nor did the effort to use the existing housing institutions (SHC and TDC) to expand housing development bear any remarkable fruits at the time of its exit from the political scene in 1981 (9).

2.4 1981 to the Present Day

The Rawlings government that took over from the previous civilian government has been pre-occupied with the institution of national economic policies aimed at reversing more than a decade of national economic decline and the institution of a national programme of sustained economic and social development. Against this background, the government launched an economic recovery program in 1983 and which was planned to be implemented in two phases. The first phase (1983–1986), known as the stabilization phase was aimed at halting the decline especially in the industrial and export commodity production sector. The second phase is the structural adjustment and development phase (1987–1989) which is embarking on growth and development with special emphasis on the provision of social services. As expected the policies implemented under the first phase of the economic recovery program have hardly brought any impact on the housing sector resulting in a continuous deterioration of the existing structures as the stock of housing in the country has hardly increased whilst population growth continues and exerts considerable pressure on the availability and affordability of existing housing. Thus the 1987 to 1989 budget statements have continually expressed a policy of encouraging Ghanaians to invest in housing. The policy emphasizes a reduction on duties and taxes payable on building materials and support is also being given to major housing development institutions to complete the numerous housing projects scattered all over the country at various stages of completion. But the extent to which these policies can help in reducing the current housing problems is yet to be determined.

Thus in a summary therefore, up-to-date housing policies and programs have failed in diverse ways to ameliorate or reduce housing problems. Their failure may be attributed to inability of the government to institute an effective and workable investment scheme to aid the most vulnerable socioeconomic groups. In addition the concept of self-help has hardly been emphasized as a way of reducing housing construction cost especially among the low income households. The impact of these housing policies can best be appreciated from the analysis of housing characteristics of the study area below.

2.5 Housing Characteristics Within the Study Area

Kumasi is a medium-sized city with a population of 348900 in 1984. Like most cities in the developing world, population growth has been very rapid, averaging about three percent per annum. Rapid increases have also been recorded in the number of households over the years (Table 1)

Table 1 Population and Households in Kumasi

Year	Population	Households
1960	180642	56126
1970	260286	66176
1984	348900	89141

source: compiled from the 1960, 1970 and 1984 national population census reports

But despite these sharp increases in the population and household numbers, the growth in the level of housing stock has been very dismaying as shown in Table 2 below.

Table 2 Housing stock levels in Kumasi.

Year	Housing stock
1960	8475
1970	11755
1980	20000
1982	22900
1984	23700

source : Land Valuation Board, Kumasi.

The general economic decline that has characterized the national economic growth, as pointed out previously, has had a corresponding setback on housing investments resulting in serious shortages particularly among the low income households of the city. The contrast between the high income, and most especially, the low income housing sectors is very impressive. The plight of the low income majority is worsened by the elites in the high and middle income brackets imposing standards for urban housing from the developed countries. Housing is generally overcrowded and seems to be getting crowded through time because of the continuous lag between the supply and demand situations. Except in the high income and some middle income areas, the mean occupancy rates ranges between 5.2 and 7.8 persons per room (9). The present housing plight of low income households has resulted in the increase in the number of unauthorised houses within the city as shown in Table 3 below.

Table 3 Levels of Unauthorised housing in Kumasi

Year	Houses built	No. Unauthorised	% Unauthorised
1972	408	144	35.3
1973	527	202	38.3
1974	699	354	50.6
1975	638	306	47.9
1976	515	284	55.1
1977	508	262	56.1

source : City Engineer's Department, Kumasi city council.

These unauthorised houses, representing those that contravene the existing laws and regulations governing the development of decent housing within the city replicates the growing inability of the housing policies and programs to meet the present housing requirements and needs. The present housing crisis is not limited to the provision of buildings alone but also the provision of all the allied services constituting the collective entity called housing.

To be able to address the housing problems of this magnitude and dimension inevitably calls for the examination of pertinent issues such as the current and future levels of housing

investment turnover within the city and more importantly among the different socio-economic groupings so that the limited available housing financial aid can be channelled to the most underprivileged and vulnerable groups with a view of increasing their housing consumption levels. This analysis, it is hoped, could form a strong basis for the evolution of a sound future housing policy not only for the city but also other cities facing similar dilemma.

Thus the study below develops a model based on Model Reference Adaptive Control System (MRAS) for predicting the future housing investment levels among the identifiable socio-economic groups within the city. It is also used to simulate the effects of anticipated investment options on the levels of housing investments vis-a-vis these groups.

3. The Model Reference Adaptive Housing Model (MRAHM)

The absence of suitable housing models to address housing problems of the large cities in Sub-saharan Africa has been stressed by various writers (5). These models are needed essentially to provide the empirical basis for the design of housing policies for these cities taking into consideration their peculiar characteristics that may be different from those existing elsewhere. Thus this modelling approach is significant in a number of ways since it characterises the research population in terms of their affordability levels, a strong point that has been missing from similar research efforts.

The socio-economic stratification of the urban population in a third world city has been demonstrated in some previous studies (14). In this study, the writer stratified the urban population in Madras city in India into high, middle and low income groups based on income and other social indicators. Similar indicators were used to stratify the housing areas of the study area, Kumasi into high income, middle income and low income housing areas (2). Following the above paradigm, the city's households were classified into high income, middle income and low income households to reflect the differences of their income levels which was used to mimic their housing affordability and investment levels.

The model, MRAHM, is the outcome of a modification of the MRAS model which represents a family of models broadly used in production control studies. The MRAS models were evolved in the late 1950'S in the field of control theory as one of the most appropriate mechanisms for making a control system 'adaptive'. Stated differently, the adoption of this control mechanism was to assure high performance when large and unpredictable variations of the plant dynamic characteristics occurred. Eversince, its application in diverse fields of study has been recorded. For example, Yamamura and Miyata have broadly applied it into the realms of social sciences, noticeably in the analysis of economic development policies (18), (17), (19), (12), (13), (1).

To avoid a repetition of giving a detailed description of the original model, as abundant literature on the topic already exists, the present study focusses only on the essential characteristics of the MRAS as relevant to the present model formulation process.

As a general model, MRAS consists of two sub-models namely the Reference model and the Adaptive model.

The Reference model may be written as follows :

$$X1(t+1)=A1 X1(t)+B1 U1(t) \quad (1)$$

The Adaptive model may also be written as follows :

$$X2(t+1)=A2 X2(t)+B2 U2(t) \quad (2)$$

where,

$X1(t+1)$ and $X2(t+2)$ are vector matrices

$A1$ and $B1$ are constant matrices

$X1(t)$ and $X2(t)$ are vector matrices

$A2$ and $B2$ are time-varying matrices

$U1$ and $U2$ are input vectors

The MRAHM is based on two explanatory variables which are the past housing stock and the past housing investment levels. These two variables were used as proxies to determine the levels of future housing stock and its attendant investment outlay. The use of this kind of relationship to determine the levels of future investment outlays has been stressed in some previous housing studies relating to both the developed and the developing countries (4), (6). In addition, to cater for the relative differences in the levels of housing investment among the socio-economic groups in the study area, the model makes provision for these stratified groups and simulations based on this framework are executed accordingly.

Based on the above thought, the original model is reframed as follows :

The Reference model for a specified socio-economic group then becomes,

$$HN(t+1)=C1+A1 H(t)+B1 Y(t) \quad (3)$$

The Adaptive model for a specified socio-economic group, accordingly becomes,

$$HS(t+1)=C2+A2 H(t)+B2 Y(t) \quad (4)$$

Where,

$HN(t+1)$ is the expected level of housing needs at period $t+1$

$HS(t+1)$ is the housing stock level associated with the period $t+1$

$H(t)$ is the level of housing stock at period t $C1$ and $C2$ are the parametric constants for the reference and the adaptive models respectively. $A1$ and $A2$ represents the coefficients of the past housing stock $B1$ and $B2$ depicts the past investment coefficients while $Y(t)$ is the housing investment outlay for the period t

Since the model deals primarily with the same city, replacing $C1$, $A1$ and $B1$ with $C2$, $A2$ and $B2$ is permissible.

The underlying objective of the MRAHM is how to determine a control input for the adaptive model so that,

$$\lim X1(t)-X2(t) =0$$

In other words, which housing investments policy options are required for the adaptive model to converge to the Reference model output i.e for the current housing investment levels to equate the required housing investment levels.

In the above proposition, we define the control input $U(t)$ (from equations 1 and 2 above) as,

$$U_2(t) = C(t+1) X(t) + D(t+1) U_1(t) \quad (5)$$

so equation (2) may be written as :

$$X_2(t+1) = \{A_2 + B_2 C(t+1)\} X_1(t) + B_2 D(t+1) U_1(t) \quad (6)$$

But as state generalized error is nothing but the difference between the state vector of the reference model and the state vector of the adaptive model, the error equation may be written as follows (13) p. 282.

$$e(t+1) = A_1 e(t) + \{A_1 - A_2 - B_2 C(t+1)\} X_2(t) + \{B_1 - B_2 D(t+1)\} U_1(t) \quad (7)$$

Miyata has pointed out that the operation of adaptation laws for $C(t+1)$ and $D(t+1)$ using $e(t+1)$ is prone to have no sense in practice. Accordingly, to overcome this problem, he introduced a priori error defined in (13) p.150

$$\hat{e}(t+1) = X_1(t+1) - \{A_2 + B_2 C(t+1)\} X_2(t) - B_2 D(t) U_1(t) \quad (8)$$

and to bridge the gap between the reference and the adaptive models by making it asymptotically equal to zero, he has incorporated some additional adaptation laws. Two rates of adaptation speeds, representing both the reference model and the adaptive model are also incorporated alongside an $n \times n$ diagonal matrix.

In MRAHM, both the reference and adaptive models adaptation Speeds may be interpreted as policy options that influence housing investments. The main objective of the adaptation speed is to bring the path of the adaptive model to closely converge on the Reference model. Accordingly, the higher the values of the speeds, the faster the path of the adaptive model converges onto the Reference model.

In addition, and as a convention, the adaptation path moves closer and closer until it converges on the reference model inferring that the difference between the two paths have been equalized to zero. The equalization process is obtained through variations in the housing investment possibilities that can be made available to the three groups in the form of inverse matrices of their housing investment coefficients.

3.1 Data

The principal data components used for this simulation are the disaggregated housing stock and investment levels within the city from the period 1983 to 1986. The disaggregation of the data was meant to take cognisance of the different socio-economic household groups within the city as they influence housing consumption and investment. Thus the

housing stock levels attributed to a specified group, it is assumed, represent the group's housing investment turnover over the duration.

The derivation of the levels of housing investment among the stratified groups involves the employment of cumbersome procedures in the light of the paucity of data on such issues in the developing countries. The procedure used entail the following. Because of the diversity of house types even among households within the same socio-economic groups, costing procedures become cumbersome and unwieldy. Thus to circumvent this problem, the study adopts representative house types and their price quotations over the 1983 - 1986 period as they are available from the State Housing Corporation in Kumasi. This housing corporation is a public organization responsible for housing development not only in the city but throughout the country. An advantage of this approach is that the corporation builds houses that are characterized as low income houses, middle income houses and high income houses to suit the various income groups. This makes the yearly price quotations suitable for adoption for this study. The problem associated with this approach is that since the corporation's houses are of high quality, and therefore commands high prices, may fail to reflect the real investment levels of these groups. But this fear can be lessened on the grounds that even though these houses are of high quality, their sizes are smaller in comparison with the average sizes of houses occupied by households within the respective income groups in the city. In essence therefore, the high quality value of these houses is compensated for by the relative large sizes of these privately owned houses.

These house prices were deflated using procedures adopted for Ghana by the Federal statistical board of West Germany (15) to counteract the inflationary tendencies that have characterized the Ghanaian economy over these years. These price quotations multiplied by the number of houses available to the relevant socio-economic group became a proxy for the groups housing investment outlay for that specific time period.

The resulting data which served as the input data for this analysis is provided below in Table 4.

Table 4

a) High income sector

Year	H (t+1)	H (t)	Y (t)
1983	4320	4120	6912
1984	4550	4320	6969
1985	4728	4550	7375
1986	4958	4758	7991

b) Middle, income sector

Year	H (t+1)	H (t)	Y (t)
1983	9490	9335	6721
1984	9604	9490	6886
1985	9770	9604	7465
1986	9978	9770	8515

c) Low income sector

Year	H (t+1)	H (t)	Y (t)
1983	9520	9425	5183
1984	9646	9520	5527
1985	9896	9646	5988
1986	10192	9896	6404

The $Y(t)$ values are expressed in units of million cedis. The cedi is the unit of currency in Ghana.

4. Model Simulation and Results

This model was simulated principally to capture the levels of the future housing stock and investment among the three socio-economic groups from the period 1987 to 2007. The underlying policy options governing these simulations were as follows :

Option 1 represents a no change option, that is the current levels of housing investment activity is expected to continue into the future.

Options 2 and 3 are policy options that draw on a social security fund which is a publicly operated fund in Ghana. This fund is constituted partly from workers contributions and partly from government subventions. These two policy options are based on a scenario which envisages a 50 percent utilization of all future contributions into the fund for housing investment and development activities as contemplated in recent government policy statements (8),

(7). The detailed formulation of these options are as follows :

Option 2 - Under this option, it is postulated that 50 percent of all contributions to the fund made by a specific socio-economic group(derived from the groups average percapita annual contributions multiplied by its household numbers) be reimbursed into housing investment and development activities specifically for that group to complement the group's housing development efforts.

Option 3 - This option on the other hand, envisages the creation of a special housing development fund with 50 percent of the contributions as in the above option. This housing development fund is to be allocated to the three groups via this approach - high income housing development - 10 percent, middle income housing development - 30 percent, and low income housing development - 60 percent to reflect the assumed magnitudes of a specified socio-economic groups number of households relative to the total number of households within the city (3), a notion based on the concept of social equity. The results of these three simulations are as presented below in Tables 5, 6 and 7.

Table 5 Simulation Results for the High Income Sector

a) Housing investment turnover (unit : million cedis)

Year	option 1	option 2	option 3
1987	8943	8943	8943
1988	11377	11650	11103
1989	7670	7842	7528
1990	8052	8243	7897
1991	8451	8663	8283
1992	8870	9104	8687
1993	9308	9566	9110
1994	9677	10050	9552
1995	10246	10556	10015
1996	10749	11088	10500
1997	11274	11644	11008
1998	11825	12227	11539
1999	12400	12837	12094
2000	13003	13477	12676
2001	13633	14146	13284
2002	14293	14848	13920
2003	14983	15583	14586
2004	15706	16352	15283
2005	16461	17157	16011
2006	17351	18001	16774
2007	18078	18884	17571

b) Housing stock levels

Year	option 1	option 2	option 3
1987	4879	4879	4879
1988	5208	5218	5205
1989	5381	5397	5377
1990	5560	5581	5553
1991	5745	5772	5736
1992	5935	5970	5925
1993	6132	6174	6120
1994	6336	6385	6321
1995	6546	6603	6529
1996	6764	6829	6744
1997	6988	7063	6966
1998	7220	7304	7195
1999	7460	7554	7432
2000	7707	7813	7676
2001	7963	8080	7929
2002	8228	8356	8190
2003	8501	8642	8459
2004	8783	8937	8737
2005	9075	9243	9025
2006	9376	9559	9322
2007	9687	9886	9628

Table 6 Simulation Results for the Middle Income sector

a) Housing investment turnover (in million cedis)

Year	option 1	option 2	option 3
1987	9086	9086	9086
1988	12606	12646	12599
1989	11908	11943	11896
1990	12631	12675	12624
1991	13378	13430	13375
1992	14150	14211	14152
1993	14948	15019	14955
1994	15772	15854	15785
1995	16624	16717	16643
1996	17505	17609	17530
1997	18416	18532	18448
1998	19357	19487	19396
1999	20331	20475	20377
2000	21338	21496	21392
2001	22379	22553	22441
2002	23455	23647	23526
2003	24569	24778	24649
2004	25721	25949	25811
2005	26912	27160	27013
2006	28145	28414	28256
2007	29420	29711	29543

b) Housing stock levels

Year	option 1	option 2	option 3
1987	10392	10392	10392
1988	10831	10835	10833
1989	11057	11064	11061
1990	11288	11297	11293
1991	11524	11536	11530
1992	11765	11779	11772
1993	12011	12028	12019
1994	12262	12281	12272
1995	12518	12541	12529
1996	12780	12805	12793
1997	13047	13075	13061
1998	13320	13351	13335
1999	13598	13633	13616
2000	13882	13921	13901
2001	14169	14214	14193
2002	14469	14514	14491
2003	14771	14820	14796
2004	15080	15133	15106
2005	15395	15452	15424
2006	15717	15779	15748
2007	16045	16111	16078

Table 7 Simulation Results for the Low Income sector

a) Housing investment turnover (in million cedis)

Year	option 1	option 2	option 3
1987	7078	7078	7078
1988	7691	7700	7820
1989	7183	7190	7287
1990	7392	7400	7500
1991	7609	7618	7720
1992	7833	7844	7948
1993	8065	8077	8184
1994	8305	8318	8428
1995	8553	8568	8681
1996	8810	8827	8942
1997	9075	9094	9213
1998	9350	9372	9493
1999	9635	9658	9783
2000	9930	9956	10084
2001	10235	10263	10395
2002	10550	10582	10717
2003	10877	10912	11051
2004	11216	11254	11397
2005	11566	11608	11754
2006	11929	11974	12125
2007	12305	13254	12509

b) Housing stock levels

Year	option 1	option 2	option 3
1987	10528	10528	10528
1988	10988	10990	10994
1989	11225	11228	11235
1990	11468	11472	11481
1991	11715	11721	11732
1992	11968	11975	11989
1993	12227	12235	12252
1994	12491	12501	12520
1995	12761	12772	12794
1996	13036	13049	13075
1997	13318	13332	13361
1998	13606	13622	13654
1999	13899	13917	13953
2000	14200	14219	14258
2001	14506	14528	14570
2002	14820	14843	14890
2003	15140	15165	15216
2004	15467	15494	15549
2005	15801	15830	15889
2006	16142	16174	16237
2007	16491	16525	16593

The results reported above clearly illustrate the severity of the anticipated housing problems within the city in the future. This is especially so when option 1 is studied in detail. Despite the infusion of the Social Security funds into the future housing investment stream, as depicted under options 2 and 3, no appreciable increases are recorded in the general levels of the housing stock and investments. It is significant, however, to stress that the third option, pivoted around the social concept of equity, succeeded to some extent in boosting the investment levels within the low income sector as compared to similar increases recorded in the other two sectors. This is therefore a significant finding worthy for consideration.

The results emanating from the Reference model section of the simulation (housing needs) are not reported here because they seemed to be unrealistic. The basis for this assertion was a comparison of these results with a previous study (3) in which buoyant results were obtained.

5. Conclusions and Directions for Future Research

This study represents one of the pioneering attempts to model future urban housing development activities in Sub-Saharan Africa, a region plagued with rapid population growth, massive urbanization and unparalleled economic decline. Specifically, the study dealt with the simulation of housing investment options among households characterized by their socio-economic differences and was subsequently applied to Kumasi city in Ghana.

The initial sections of the paper which dealt with the sources of the current housing problems and the subsequent literature review on Ghana's housing policies were meant to provide useful insights into the nature of the existing problems.

The model, adapted from the MRAS framework provided an effective and sound basis for this assessment. The resulting output indicates a future promise for the model in the analysis of urban housing problems within the third world setting and elsewhere.

In the future, it is our intention to improve upon the predictive capabilities of the model, especially the Reference model so that it can provide an effective basis for predicting the future levels of housing needs within the city.

It is our contemplation to explore and simulate numerous and more diversified sources of investments options for meeting the future housing needs within the city in our subsequent studies.

References

1. Adi, E and Yamamura, E. (1988): A study on model reference adaptive control in economic development(VIII) - model reference adaptive interregional migration in Indonesia, Environmental Science, Hokkaido, Graduate School of Environmental Science, Hokkaido University.
2. Asabere, P.K. (1981): The price of urban land in a chiefdom - Empirical evidence on a traditional African city, Journal of Regional Science, Nov. 529-539.
3. Asiedu, Alex Boakye (1989): A study on the dynamic assessment of housing investment options for Kumasi city in Ghana, master thesis, Graduate School of Environmental Science, Hokkaido University.

sity.

4. Chang, Chin-OH (1986): Explanation and forecasting of National housing investment in Taiwan(ROC), Korea(South), Japan and the U.S.A., unpublished doctoral thesis, University of Pennsylvania.
5. Christiaan Grootaert and Jean-Luc Dubois (1986): The demand for urban housing in the Ivory Coast, World Bank Publications, (working papers series), Washington.
6. Conway, Richard S, Jr and Howard Charles T. (1980): A Forecasting model for regional housing construction, Journal of Regional Science, Vol. 20 Number 1.
7. Government of Ghana (1989) : Ghana today, Information Services Department, Vol. 1 Number 2.
8. Government of Ghana (1987) : National Programme for Economic Development (revised), Accra.
9. Graham Tipple, A. (1982) : A manual for the course on Housing in Bsc. programme, Dept. of Planning, U.S.T, Kumasi.
10. K.C. Tan and R. J. Bennet (1984): Optimal control of spatial systems, George Allen and Unwin.
11. Landau, Yoan D. (1979) : Adaptive control, The model reference approach, Marcel Dekker.
12. Miyata, Y. and Yamamura, E. (1986) : A study on reference adaptive control in economic development (III) : model reference I-O analysis, Environmental Science, Hokkaido, Graduate School of Environmental Science, Hokkaido University.
13. Miyata, Y. and Yamamura, E. (1987) : A study on model reference adaptive control in economic development(V) : model reference adaptive turnpike theorem (1), Environmental Science, Hokkaido, Graduate School of Environmental Science, Hokkaido University.
14. Thrimurthy, A.M. (1988) : A study on the formulation of urban development model with reference to essential environmental facilities of an urban area of a developing country, unpublished doctoral thesis, Graduate School of Environmental Science, Hokkaido University.
15. Statistics on Ghana (1985): Federal Statistics Office, Wiesbaden (West Germany) (in German).
16. United Nations Publications (1985) : ST/ESA/SER. R/57, New York.
17. Yamamura, E. (1984) : A study on model reference adaptive control in economic development(1), Environmental Science, Hokkaido, Graduate School of Environmental Science, Hokkaido University.
18. Yamamura, E. (1985)(a): Optimal and Reference adaptive Processes for the control of Regional income disparities, Papers of the Regional Science Association, Vol. 56.
19. Yamamura, E. (1985)(b): A study on model reference adaptive control in economic development(II), Environmental Science, Hokkaido, Graduate School of Environmental Science, Hokkaido University.