Socioeconomic Analysis of Informal Settlement Growth in Dar es Salaam:

The concept for an agent based model

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February, 2010

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by

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Thesis submitted to the International Institute for Geo-information Science and Earth Observation in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation, Specialisation: Urban Planning and Management

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Abstract

Dar es Salaam's informal settlements are home to 70 – 80 % of the city's residents and are characterized by high housing densities, unstructured road infrastructure and inadequate water, electricity, and sewerage services. In such an informal settling, predicting land-use change may pose a challenge for conventional modelling techniques. In this study, empirical evidence was used to develop the concept for a spatially-explicit agent based model that can later be used to predict land-use change in an informal settlement in Dar es Salaam. The model incorporates the socio-economic drivers of development, the biophysical attractive and deterrent forces that affect location decision-making by households, as well as the effect of the macroeconomic conditions that impact the pace of development. A short household questionnaire survey and supplemental macroeconomic data were used to identify agents and determine their behaviour and its exogenous influences. The model concept was validated by third party individuals for its theoretical and logical correctness. The model is comprised of two main levels – micro and macro, and is influenced by global parameters, which should allow for experimentation with the computer-based model, and shows how the settling of agents at the local level affects the characteristics of the global system (macro-level). The successful implementation of the model concept lends itself to application to larger geographic locations within the city.

Acknowledgements

The production of this thesis would not have been possible without the guidance and support of friends, relatives, and scholars. I would like to express my deepest gratitude to my supervisors Dr. Johannes Flacke and Dr. Richard Sliuzas for all the direction they provided, especially with regards to the structuring and organization of the work and for ensuring my ambitions did not extend beyond my capabilities (smile). I must also extend a warm thank you to the three experts who reviewed the model concept, Mr. Friedrich Krebs, Professor Dr. Volker Kreibich, and Ms. Flavia Feitosa (soon to be Dr. Feitosa). Special thanks to Ms. Feitosa and Dr. Tatiana Filatova for providing helpful hints and critical reviews that go beyond the field of agent based modelling. Also, a special thank you to Germain Furaha, Richard Emile, and Dr. Alphonce Kyessi from Ardhi University for all the support they provided in carrying out the household survey in Hanna Nassif. My appreciation is also for my CEO Mrs. Beverly Castillo for believing in her staff and for partly granting me the opportunity to be here under the conditions that I am. Also, thanks to my friends and co-workers in Belize. Thanks to my parents Yolanda Young and Elgene Young, my sister Esther Silva, my four brothers, and the rest of my family for your words of encouragement and for believing in me throughout. Thank you to Katrin Siegler for being my quiet source of inspiration when it mattered most. And last but not least my friends and lecturers in ITC and PGM department for making this educational experience fun and rewarding beyond comparison.

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Acronyms and Abbreviations

ABM	Agent Based Model
ABMS	Agent Based Modelling and Simulation
ALMA	Agent Based Land Market model
CBD	Central Business District
CPI	Consumer Price Index
DEED	Dynamic Ecological Exurban Development
ERP	Economic Recovery Program
ESAF	Enhanced Structural Adjustment Facility
Forex	Foreign Exchange Market
GDP	Gross Domestic Product
GIS	Geographic Information System
IMF	International Monetary Fund
ITC	International Institute for Geo-Information Science and Earth Observation
JUNG	Java Universal Network/Graph Framework
MASON	Multi-agent Simulation Toolkit
MASUS	Multi-Agent Simulation for Urban Segregation
NESP	National Economic Survival Program
O-O	Object-Oriented
OBEUS	Object-based Environment for Urban Systems
OECD	Organisation for Economic Co-operation and Development
OS	Operating System
PPI	Producer Price Index
PRSP	Poverty Reduction Strategy Paper
PSS	Planning Support System
RAMCO	Rapid Assessment for Management of COastal Zones
REER	Real Effective Exchange Rate
Repast	Recursive Porous Agent Simulation Toolkit
SLUCE	Spatial Land Use Change and Ecological Effect
SME	Subject Matter Expert
SOME	SLUCE's Original Model for Exploration
SPSS	Spatial Planning Support System
THB	Tanzania Housing Bank
TShs	Tanzanian Shillings
UCLAS	University College of Land and Architectural Studies
UML	Unified Modelling Language
UN	United Nations
US	United States of America
WPI	Wholesale Price Index
WUA	Water Usage Associations

XML	Extensible Markup Language

1. Introduction

This chapter introduces the research task by providing the context within which the study is conducted. It first describes the research problem then briefly discusses the approach used in addressing it, making clear the research aim and associated objectives. In this chapter the reader will also find the conceptual framework which describes the scope of the research and theoretical framework which provides the basis for the discussion of findings in subsequent chapters. There is also a short description of the case study area.

1.1. Background

In Tanzania, the urban population grows at an average of 6 % per annum, twice that of the national average (World Bank, 2002b). Unfortunately, due to increasing levels of poverty, population growth and lack of sustainable housing policy, urban growth is absorbed into informal settlements (ibid). Absorption of the population into informal settlements, on the one hand, is due to the lack of provision of formal or surveyed plots for the greater portion of the urban population. W.J. Kombe & V. Kreibich (2000) mention 6.8 % of plot allocations fulfilled between 1978/79 and 1990/91 in the city of Dar es Salaam; Kironde (2006) states approximately 3.4 % of the demand fulfilled between 1990 and 2000.

1.1.1. Definition of informal settlements

Informal settlement in many cases refers to the illegal or unlawful occupation of land; however, in Dar es Salaam this is not necessarily the case. In Jakarta, for example, informal settlements occupy disputed land, state land, and private unoccupied land (Winayanti & Lang, 2004). In Nairobi, informal settlements are identified by a number of characteristics, two of which are that owners of housing structures have either quasi-legal or no rights at all and that majority of the inhabitants have low or very low incomes (Alder, 1995). In Dar es Salaam, on the other hand, informal settlements often comprise both affluent and poor residents (W.J. Kombe & V. Kreibich, 2000). Furthermore, up to 98 % of the houses in Dar es Salaam have been built by private individuals (ibid).

1.1.2. Problems associated with informal settlements

Rapid, uncontrolled urbanization in Dar es Salaam poses a problem to city government as their capacity to keep pace in providing infrastructure and public services to residential areas is severely strained (Wilbard J. Kombe & Volker Kreibich, 2000; Stren & White, 1989; World Bank, 2002b). This phenomenon is characteristic of informal settlements in other major cities like Nairobi and Cairo where informal settlements are characterized as having problems in transportation, lack of usable open spaces (El-Batran & Arandel, 1998), inadequate drainage and sewerage, limited ability to provide roads, pathways, water (Alder, 1995; El-Batran & Arandel, 1998), poor environmental conditions and high crime rates (UN-Habitat, 2008).

1.1.3. Population density in Dar es Salaam's informal settlements

In Tanzania, the city of Dar es Salaam seems to be suffering the blunt of the country's urban problems, being the largest city in Tanzania with an estimated population of 3.5 million in 2000 (seven times the size of the second largest, Mwanza) and growing at an average rate of 8 % p.a. (World Bank, 2002b). It is estimated that 70 % or so if its population live in informal settlements (Kironde, 1995; W.J. Kombe, 1995; World Bank, 2002b). Kironde (2006), based on new findings, has subsequently proposed that the population exceeds 80 %. In 2002, the World Bank (2002) quoted population densities of up to 1,500 persons / Ha, while middle to high income residential areas in Nairobi record densities as low as 50 persons / Ha (Alder, 1995). High densities resulting in overcrowding coupled with poor sanitation and sewage disposal in proximity to water facilities may increase the risk of contracting certain diseases (UN-Habitat, 2003).

1.1.4. Source of urban growth in Dar es Salaam

Rapid urbanization in Dar es Salaam has been attributed to sustained increases in rural-urban migration (2-3 % p.a.) coupled with a high birth rate. Residents from informal settlements located in peri-urban areas live in a somewhat symbiotic relationship with inner city residents (W. J. Kombe, 2005), whereby they engage themselves in urban agriculture for supply to inner city areas. These peri-urban areas further house low-income residents who provide labour to the inner city, while benefiting from employment and services from the same (ibid). Immigrants are said to originate from various sections of Tanzania outside the city of Dar es Salaam, mostly from the coastal strip running from the Tanzania-Kenya border to the Tanzania-Mozambique border and the northern and eastern regions of Tanzania (Hakuyu, 1995).

1.1.5. Predicting spatial change in the urban environment

Predicting urban land use change is important if city managers and municipalities are to provide, even at minimum standard, necessary infrastructure and services to their residents. Forecasting where and how urban change will manifest itself, however, is a challenge for any city and its planners. Thus, it is envisaged that if the growth process of urban and informal settlements is better understood it can be modelled and applied in real situations for the prediction of growth under likely future scenarios. In this light, it is useful to be able to determine the underlying forces that drive the growth and expansion of informal settlements to be used and applied in a modelling environment in order to pre-empt and prepare for this inevitable growth. Veldkamp and Lambin (2001) propose that spatially explicit modelling can be used to conduct experiments that test our understanding of key processes and for describing them in quantitative terms. As a simplification of reality, a model can allow the user to structure data collected from the real world in a manner that is easily interpreted and understood by the scientific world as well as the general public.

In this study, the process which is to be explored is the growth of informal settlements within the setting of a typical developing country city. As mentioned previously, models can lend aid in the

understanding of key factors underlying the processes involved in the system that is being simulated. In the case of informal settlements, appreciating the factors and understanding the economic (and social) processes is of vital importance if planners and urban managers hope to progress from wishful thinking in shaping the spatial structure and form of urban Tanzania and other sub-Saharan African cities (W. J. Kombe, 2005).

1.2. Hanna Nassif: the case study

The settlement of Hanna Nassif was selected for this case study due to the volume of research that has been conducted and is available for this particular area. The settlement was one of three focused on in Sliuzas, Ottens et al. (2004), in which problems of managing informal development at the local level were discussed. Between 1994 and 1998 the settlement was also the target of a community infrastructure upgrading project funded by the Ford Foundation and the International Labor Organization World Bank (2002b). Ramroop (1995) further discusses how GIS technology could be used in infrastructure upgrading in Hanna Nassif by deriving a digital surface model and finding the shortest routes for drainage and road networks. Sheuya (2004) further includes this settlement as one of two case studies in his research on the housing transformation process in Dar es Salaam.

Hanna Nassif forms one of three subwards found within the administrative boundary of the Hanna Nassif Ward in Dar es Salaam. It is located approximately 4.5 km from the city centre (Figure 1-1). It is bounded on the north by a planned residential area, to the west by Kawawa road, and the Msimbazi river valley (Figure 1-2) forms its southern and eastern borders (Sheuya, 2004). The settlement is one of the oldest in Dar es Salaam, having been established in the 1960's (Sliuzas, et al., 2004). It comprises mostly low-income residents (ibid). In 2002, its population was estimated at 13,000. Its areal coverage is around 62.5 Ha, rendering a population density in 2002 of 210 persons / Ha. Based on the Tanzania census of 2002 (The United Republic of Tanzania, 2002) which quotes an average household size of 4.2, the number of households in Hanna Nassif in 2002 was approximately 3,100.

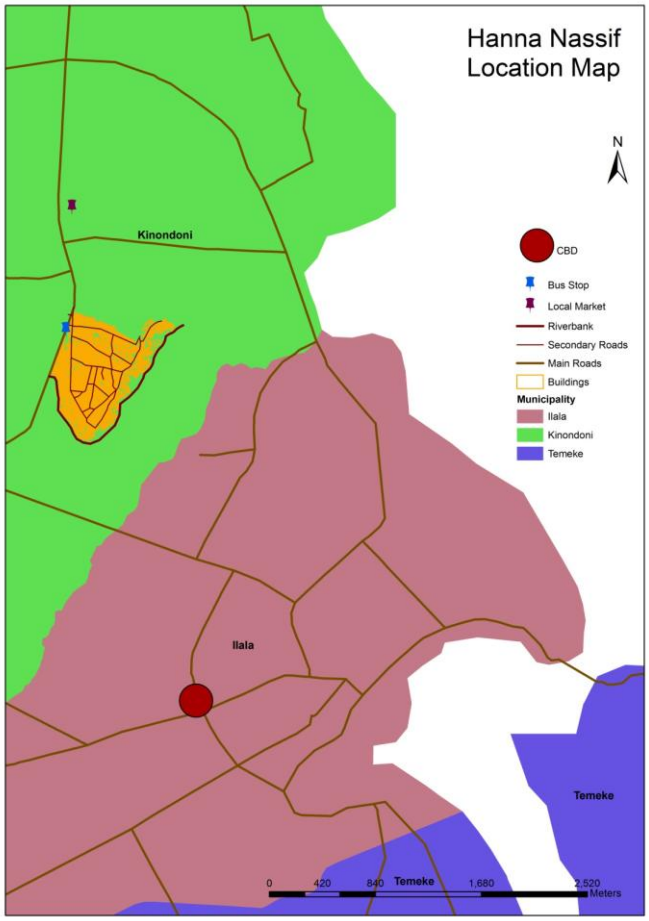

Figure 1-1: Hanna Nassif location

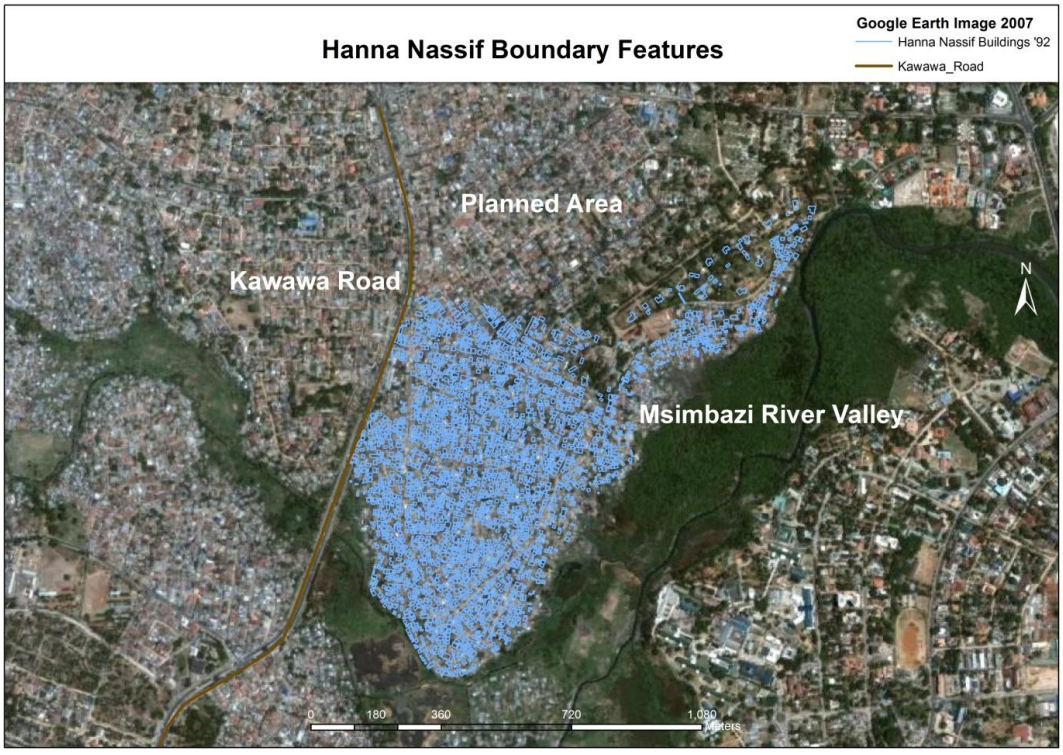

Figure 1-2: Hanna Nassif boundary features

1.3. Research problem

This section discusses what has been stated in literature as being the major factors influencing the growth of informal settlements in Dar es Salaam and other developing country cities. It further talks about the main sources of income for housing construction in these informal settings. Finally, there is some discussion of why agent based modelling is the chosen option for modelling the growth of informal urban areas.

1.3.1. Factors affecting growth of informal settlements

The growth phenomenon exhibited by informal settlements is a dynamic and complex process influenced by economic, socio-cultural, and biophysical factors. Sliuzas, Ottens et al. (2004) separates these factors into environmental, physical, and socioeconomic. Kombe (2005) highlights social and economic factors. Hakuyu (1995) discusses socioeconomic and physical characteristics of informal settlements in his analysis of spatial growth. The actual volume of housing construction taking place may be a function of households' economic potential at any given time. Population growth alone may not be the best predictor of spatial growth in informal settlements; instead the financial capacity to purchase plots and build houses may be a more adequate way of estimating housing volume.

1.3.2. Economic factors

The economic process itself is affected by a multifaceted set of influences, which may include physical factors at the micro-level and other factors at the macro-level. Physical factors such as proximity to amenities (CBD, roads, health services, schools, markets, industrial sites), upgrading and land quality will have individual impacts on other factors such as residents' utility and land price, which in turn affects affordability. Land price being determined by intrinsic and external factors reflects the principles of hedonic pricing (Grevers, 2007). Affordability of housing construction may be influenced by the cost of materials and labour (if this is sought externally). Macro-level economic influences on housing construction may include GDP, inflation, and real depreciation. Micro- and macro-level economic conditions would need to be studied in tandem as these are interrelated.

1.3.3. Sources of financial capital for housing

Financial capital can be derived from two sources, one of which is available stocks. The preferred measurement of available stocks is household savings (DFID, 1999). Savings can be held in cash, credit access, bank deposits, or other liquid assets (ibid). Unlike in planned residential areas which may comprise middle to high-income residents with some access to credit, residents in informal settlements, particularly the low-income residents, do not have regular access to credit for housing purposes. An attempt made through the Tanzanian Housing Bank (THB) was claimed to be unsuccessful in providing access to credit for housing for the urban poor and saw its demise around 1993 (The African Union for Housing Finance). Due to lack of mortgage facilities Tanzanians prefer to acquire plots and construct their houses at their own pace (ibid). Sheuya (2004) determined that of the 33 interviewees from two settlements surveyed, almost all used a portion of income to fund

housing construction, reiterating that savings remains the main sources of funding. Other sources identified include retirement funds, inheritance, and dowry (ibid).

1.3.4. Why ABM for modelling informal settlement growth

Agent based models (ABMs) are considered a special type of models as they are able to show how individual behaviour and decision-making can result in complex, emergent phenomenon. In Dar es Salaam, the lack of state intervention and failure in planning policies in informal settlements has encouraged the informal sale and distribution of land by private individuals and the subsequent construction of housing. This is evident in Kironde's (1995) survey where only 15 % of landowners held an official certificate of title or letter of offer to authenticate rights to land. Yet, most of the landowners claimed to have purchased the land they own (ibid). With the continued informal purchase and sale of land, it is understood that the emergent phenomenon of growth of informal settlements in Dar es Salaam is the result of individual and household decision-making. The decision to alter, extend, or construct a new housing structure may result from varying levels of dissatisfaction with present housing conditions, but is also highly dependent on the household's financial capabilities (Seek, 1983). Notwithstanding the capacity of other types of models such as cellular automata to simulate changes in urban land-use and land cover, ABM's ability to simulate individual behaviour is where its advantage lies in capturing informal processes and their effects on urban and peri-urban land-use change. In an informal setting such as this, understanding individual behaviour forms an intricate part of understanding settlement dynamics; thus agent behaviour forms the core of the model. An ABM is therefore applicable in this case due to the fact that it "takes the agent perspective first and foremost" (Macal & North, 2006, pg 78).

1.4. Research objectives

This study thus uses a series of qualitative and quantitative methods to unravel the dynamic socioeconomic process underlying the physical changes occurring in informal settlements in Dar es Salaam, Tanzania in an attempt at developing a conceptually-based agent based model that will later be transformed into a computer model. Specifically, it intends to capture the micro- and macro-level socioeconomic forces driving the housing process. In this section, the main research aim and its objectives are listed.

1.4.1. Aim

To develop the concept for an agent based model based on the socioeconomic and physical factors influencing the housing construction process in the informal settlement of Hanna Nassif, Dar es Salaam.

1.4.2. Objectives

1. To analyze micro-level agent decision-making behaviour in residential location and the economic processes which result in housing construction activity;
2. To determine the effects of macro-economic conditions and policies which have the potential of influencing agent behaviour in the housing process; and
3. To develop and validate a conceptual model of residential decision-making behaviour of household agents based on the micro- and macro-level driving forces affecting behavioural patterns.

1.5. Research questions

Here the research questions are listed below the objective which they relate to.

Objective 1: To analyze micro-level agent decision-making behaviour in residential location and the economic processes which result in housing construction activity

1.1 What are the socioeconomic factors which trigger housing construction?
1.2 What are the budget constraints for households which are intent on constructing new housing structures?
1.3 What are the optimal factors that determine residential location decision-making?
1.4 What are the constraints that affect location choice?
1.5 What neighbourhood socioeconomic structure favours location choice?

Objective 2: To determine the effects of macro-economic conditions and policies which have the potential of influencing agent behaviour in the housing process

2.1 What macro-level policies have been implemented during the historical growth of the informal settlement?
2.2 What are the historic macro-level economic conditions surrounding the growth of the informal settlement?
2.3 How do these macro-level economic conditions and policies affect volume of housing construction?

Objective 3: To develop and validate a conceptual model of residential decision-making behaviour of household agents based on the micro- and macro-level economic driving forces affecting behavioural patterns

3.1 How can a conceptual model be developed from the information gathered on agent behaviour and its macroeconomic influences?
3.2 How can the model be validated to ensure it adequately captures the growth of informal settlements and achieves its intended purposes?

1.6. Conceptual framework

Sargent (2000) has developed a simplified version of the modelling process, which is somewhat different from others described in literature, (e.g. Gao, Freech, & Madey), because it includes the validation of the conceptual model, which underlies the logic of most land use/land cover change ABMs. Stages of the modelling process excluded from that found in Sargent's (2000) include development of the computerized model and the associated computerized model verification and operational validity. This study involves the socioeconomic analysis and modelling of the growth of informal settlement, using Hanna Nassif as a case study. The informal settlement growth then becomes the problem entity (Figure 1-3). Primary and secondary macro- and micro-economic and socioeconomic data are obtained from the informal settlement, literature and other means. The data is analyzed both by computer-based quantitative and qualitative means (interpretation). In the conceptual model development process analyzed data is interpreted, structured, and translated into agent behavioural rules, which may be altered depending on the macro-economic situation (exogenous forces). In this context, the computer based ABM to be developed can be used to analyze patterns of growth under plausible future macroeconomic and demographic scenarios. The conceptual model validation process is conducted by Subject Matter Experts (SMEs) (Defense Modeling and Simulation Office, 2006) who review the model's concept and individual elements to ensure that its theories and assumptions are correct and that the model's representation of the phenomenon studied is reasonable for the intended purpose of the model.

There are three feedback loops in the framework. The first is that the interpretation of analyzed data can possibly identify the need to obtain further data or information from literature. The second is that the SMEs can suggest that the model be restructured. Third, based on ideas for restructuring received from SMEs, the need to collect further data or information may be necessary.

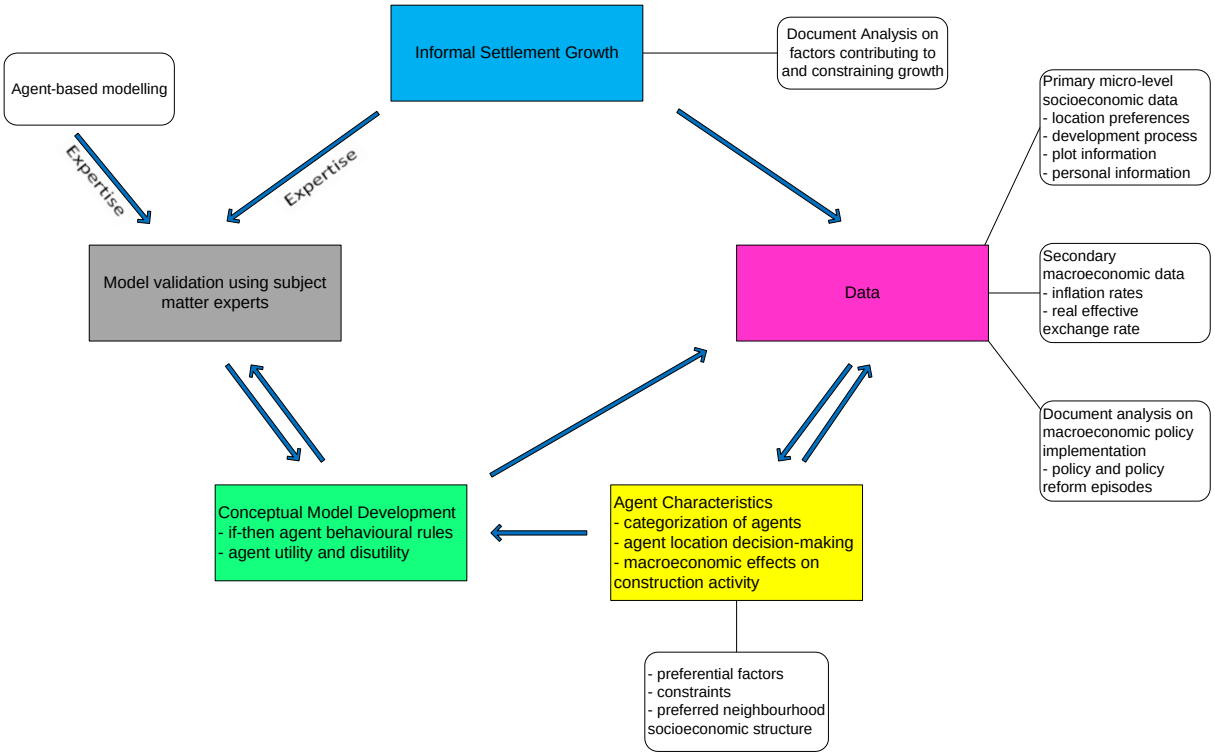

Figure 1-3: Conceptual Framework

1.7. Research design

This study is categorized as qualitative and retrospective research which uses the informal settlement of Hanna Nassif as a case study. The conceptual model is built using primarily qualitative data to which some quantitative measures of analysis were applied. The operational plan under which the study took place consists of six phases, including: 1) document analysis (which incorporates: analysis of the growth of informal settlements and a review of macroeconomic literature), 2) collection of socioeconomic and macroeconomic data, 3) analysis and interpretation of data to identify agents and determine agent behaviour, 4) structuring of behavioural information, location preferences, and internal and exogenous influences into a conceptual model, 5) model validation using subject matter experts, and 6) presentation of results and further recommendations. Each specific phase is described briefly below. Methods used to answer individual research questions are described in Section 3.2.

Document analysis: this was conducted in order to gain an understanding of two relevant areas of this research.

1. Positive and negative socioeconomic, biophysical factors impacting the growth of informal settlements, and
2. Review of macroeconomic literature which provided a breakdown of different policy periods, along with the successes and failures of each policy or type of policy.

Collection of socioeconomic and macroeconomic data: Primary data was collected by means of household interviews held with 38 house owners within the settlement of Hanna Nassif. Secondary data on the real effective exchange rate and inflation rates were collected from official reports, working papers and world databases that are prepared, published, or managed under the auspices of recognised institutions and organizations such as the Wold Bank and International Monetary Fund (IMF).

Analysis and interpretation of data: The purpose of the analysis of primary and secondary data collected is to identify agents and determine housing construction behaviour and location preferences. Furthermore, the effects of macro-level economic performance and policies on agent behaviour were determined at this stage. The specific type of analysis applied was dependent on the research question being answered and is presented in Section 3.2.

Structuring of conceptual model: Agent behaviour and its internal and exogenous influences were structured in a graphical diagram with accompanying description in text. Then, agent behaviour and its influences were structured in a matter that enables easy transformation into a computerized agent-based model.

Model validation using subject matter expert interviews: The initial draft of the conceptual model was validated by third parties called Subject Matter Experts (SMEs). The purpose of the validation exercise was twofold: (1) to determine the fitness of the representation of the individual elements in the model, and (2) to assess the overall capability of the model. Two different types of SMEs were selected based on individual areas of expertise and experience, i.e. experts with knowledge and experience in the area of growth of informal settlements in Dar es Salaam and individuals with expertise and experience in working with ABMs.

Presentation of results and further recommendations: The findings of the research are presented to relevant parties. Recommendations were also made for further research.

1.8. Theoretical framework

This section sets the background for the discussion of the findings in Chapters 4, 5, and 6 of this document. The theoretical bases described herein provide a clearer understanding of and justification for many of the results obtained from the document analysis and analysis of household survey results and macroeconomic variables.

1.8.1. The micro-economy

This section covers microeconomic theories which are relevant to the micro-level household behaviour covered in this study. The main theories discussed are consumer theory, which includes budget constraint and consumption set, the initial endowment, and preferences and utility.

Consumer Theory

In studying consumer behaviour and choices in modern consumer theory, it is assumed that the key characteristic of a consumer consists of three essential components: the consumption set, initial endowments, and the preference relation (Tian, 2009).

Budget constraint and consumption set

The consumption set is the set of all affordable consumption bundles, which is described by a set of prices (one for each possible good) and a budget. The **budget constraint** can be considered an accounting entity that describes the consumption options available to an agent with a limited income or wealth to allocate among various goods (Tian, 2009). The budget constraint captures the ability of the consumer to afford certain consumption sets.

Initial Endowment

The initial endowment represents the amount of various goods the consumer initially has and can consume or trade with other individuals (ibid).

Preferences and Utility

From a given set of affordable goods in a limited resource economy, the consumer is said to have certain preferences. The preference order should be able to satisfy the properties of completeness, reflexivity and transition (termed “complete”, “reflexive”, and “transitive”). The preference relation of two goods within a certain set is complete if either the preference for good x is greater than that of good y or vice versa ($x \geq y$ or $y \geq x$). The relation is reflexive if each good is as good as itself ($x \geq x$). In a set of three goods x, y, and z, the preference relation is transitive if $x \geq y$ and $y \geq z$, then $x \geq z$; this requires that the consumer is consistent in his/her preference relations (Tian, 2009). If a preference relation satisfies all of the properties mentioned above it is called a preference ordering (ibid).

Preferences can sometimes also be represented by utility functions. This may be the preferred option when attempting to use calculus methods. Examples of utility functions include Linear, Leontief, and Cobb-Douglas. The Linear function describes perfect substitution between goods, the Leontief describes perfect complement between goods, while the Cobb-Douglas utility function is commonly used for illustrative and empirical purposes (Tian, 2009).

The goal of the consumer is assumed to be utility maximization, which is restrained by certain constraints, principally income and prices. A rational consumer will always choose the most preferred bundle of goods from a set of feasible alternatives (Hanley & Spash, 1993).

Cobb-Douglas Utility Function

Any utility function of the form in Equation 1-1 below with $a>0$ and $b>0$ is called a Cobb-Douglas Utility function (O'Toole, 2005). An example is shown in Equation 1-2.

$$U(X_1 X_2,) = X_1^a X_2^b$$

Equation 1-1: Cobb-Douglas utility function

$$U(X_1 X_2,) = X_1^{1/2} X_2^{1/2} \qquad (a = b = ½)$$

$$U(X_1 X_2,) = X_1\ X_2^3 \qquad (a = 1, b = 3)$$

Equation 1-2: Examples of Cobb-Douglas utility function

The Cobb-Douglas utility function has been modified for use in different disciplines, however. For example, Brown and Robinson (2006) use a modified utility function in an agent-based model in which agents evaluate the utility they would attain from a set of randomly selected residential locations. The modified function is shown in Equation 1-3. In this equation, $u_r(x,y)$ is the utility of the location *(x,y)* for the resident *r*; αir is the weight the resident places on the factor *i*; β_i is the preferred value on the factor *i* and is assumed to be constant for all residents; $\gamma i(x,y)$ is the value of the factor or component *i* at location *(x,y)*, and *m* is the number of factors evaluated (Brown & Robinson, 2006). Every agent has a preference weight for each factor evaluated and all preference weights are constrained to sum up to 1. In this model, the values for agents' preference weights are obtained from survey data (ibid).

$$u_{r(x,y)} = \prod_{i=1}^{m} (1 - \left|\beta_i - \gamma_{i(x,y)}\right|)^{\alpha_{ir}}$$

Equation 1-3: Modified Cobb-Douglas utility function

1.8.2. The macro-economy

This section first defines what is meant and covered in macroeconomics and discusses relevant macroeconomic variables studied to analyze the performance of domestic economy. It closes with a discussion of two of the most relevant macroeconomic variables in the developing country context, the real effective exchange rate and inflation rate and an explanation of how they relate to each other.

Macroeconomics

Macroeconomics is the study of national economies and the determination of national income. It is primarily concerned with variables which follow systematic and predictable paths of behaviour and can be analysed independently of the decisions of the agents who determine their level. Some of these variables include economic output (GDP), inflation, employment and unemployment rates, balance of payments (trader performance with other countries), interest rates, government budget balances and finance, and productivity.

Macroeconomic variables

A country's exchange rate is the price at which purchases and sales of foreign currency or claims made on it take place. It is the amount of one currency that must be paid to obtain one unit of another currency (Lipsey & Steiner, 1972). It can be considered a conversion factor, a multiplier, a ratio, or a fast moving price in the economy (Piana, 2001). Two main types of exchange rates exist: nominal and real. Nominal exchange rate is that which is established on currency financial markets called "forex markets", which are similar to stock exchange markets. The nominal rate may be fixed by the central bank or reported daily by newspapers. The real exchange rates are the nominal rates corrected by inflation measures.

Another classification of exchange rates is based on the number of currencies taken into account. Bilateral exchange rates relate to two countries' currencies. Multilateral exchange rates are computed in order to judge the general dynamics of a country's currency toward the rest of the world. It is calculated by taking a basket of different currencies, selecting a meaningful set of relative weights, then computing the "effective" exchange rate of the country's currency (Piana, 2001).

Real Effective Exchange Rate and the Wholesale Price Index

The real effective exchange rate (REER) is defined and measured as the ratio of the domestic price of non-traded goods to traded goods (non-traded goods : traded goods) within the country. The REER may be better measured using a tradables price index, which is typically proxied for by relative wholesale price indices (WPI) or producer price indices (PPI) in both the home and foreign country (Y. Li & Rowe, 2007).

In principle, a country's REER measure should include all trading partners that compete with domestic producers either directly or indirectly through third markets. However, the data necessary for this is commonly unavailable. Thus, the number of currencies considered tends to be limited. As long as a significant majority of a country's trade is accounted for in the partners chosen, the impact on the REER index due to excluded partners should be marginal (World Bank, 2002a). An example for Tanzania can be found in Table 1-1**.**

The country's balance of payments can affect exchange rates. Foreign currency is gained when goods are exported and lost when goods are imported (Lipsey & Steiner, 1972). Therefore data on shipments of exports and arrivals of imported goods are used as proxy for demand and supply of foreign currency. The flow of imports and exports determines the demand for particular currencies on the global market which drives the bidding for and subsequent increase or decrease in worth (ibid). For example, an increase of imports from the United States results in an increase in demand for the US Dollar, which means there would be bidding up for the Dollar and subsequent appreciation of the real exchange rate in local currency as compared to the Dollar. This further leads to a contraction of traditional export sectors and a loss of export competitiveness (Y. Li & Rowe, 2007).

Trading Partners	1975	1985	1995	2000	2005
United Kingdom	12.7	14.4	8.0	11.3	4.2
United States	10.2	3.2	3.8	3.3	2.9
China	7.7	1.3	3.6	3.1	10.1
Germany	7.5	12.7	5.0	5.3	3.9
Saudi Arabia	7.2	2.8	3.7	2.6	2.2
Kenya	6.4	1.6	10.5	5.8	6.4
Japan	4.4	8.4	7.1	7.9	3.6
Italy	3.3	8.6	2.9	2.0	2.2
India	3.0	1.5	5.4	8.3	7.4
Netherlands	2.9	4.3	2.9	3.4	3.5
Singapore	2.7	2.0	2.5	0.6	0.4
Sweden	2.2	2.8	1.3	0.8	1.8
Belgium	2.1	3.0	2.1	1.5	1.5
Denmark	2.0	2.1	1.1	1.1	0.2
South Africa	0.0	0.0	7.8	8.5	10.3
United Arab Emirates	0.0	2.1	3.2	2.8	5.5
Other trading partners	25.6	29.0	29.0	31.7	33.7

Table 1-1: Major trading partners for Tanzania 1975-2005[1]

Inflation and the Consumer Price Index

Inflation is a rise in the general price level of goods and is reported in rates of change. The inflation rate is determined by finding the difference between price levels for the current year and previous given year. The answer is then divided by the given year and then multiplied by 100. To measure the price level, a variety of goods are selected to construct a price index such as the consumer price index (CPI). Home and foreign price levels are measured by respective CPIs (Y. Li & Rowe, 2007); CPI measures cover the price of both traded and non traded goods.

In North America and Europe, various theories have been postulated regarding the source of inflation. These include demand-pull, which includes upward bidding of prices due to rise in demand; cost-push, arising from unions' power where members request raises in wages which are then absorbed by the producing firm and translated into a rise in the price of goods; price-push, which is similar to cost-push but caused by the firms themselves and not unions and usually occurs when certain firms are in monopoly; structural rigidity, which relates to the slow movement of resources in the economy; and expectational inflation which are expected raises in wages and prices resulting from a rise in demand (Lipsey & Steiner, 1972). In less developed countries however, for example in South America, inflation may be caused by expansions of the money supply due to large and persistent governmental budget deficits caused by heavy investment expenditure that are not covered by tax receipts (ibid).

Inflation (or price-level change) is important for three main reasons. First, different prices change at different rates, so inflations affect relative prices and therefore influence the allocation of resources. Second, inflations lower the real income of anyone living on an income fixed in money terms. The purchasing power of money, and thus living standard, is reduced so people cannot afford to purchase the same quantity of goods with the same amount of money. Furthermore, wages do not increase at the

[1] Source: Y. Li & Rowe, 2007

same rate of the inflated prices. Individuals who are not members of strong labour unions, those employed on a contractual basis, and those on fixed income (like retirees) especially suffer from inflated prices. Thirdly, unanticipated inflations redistribute income from lenders to borrowers, especially if the interest rate is less than the rate of inflation experienced (Lipsey & Steiner, 1972).

Tanzania's CPI includes price fluctuations of food, drinks and tobacco, clothing and footwear, rents, fuel, power, water, furniture and household equipment, household operation and maintenance, personal care and health, recreation and equipment, transportation, education, and miscellaneous goods and services.

REER and CPI Relationship

There is a direct relationship between inflation and real exchange rates of domestic currency. Two types of inflation exist: monetary and price inflation. Monetary inflation occurs when there is a surplus of currency within the country. This usually results from government printing of more notes. As a result, there is more money in circulation that is backed by the same quantity of assets; each monetary unit is then backed by fewer assets. This means that the money winds up being worth less (devaluation of local currency). Thus, locally prices increase, i.e. price inflation or price level increase, to ensure that the same value is attained from the goods as previous to the devaluation (Davidmann, 2006). Thus, when analyzing inflation and its effects it is also useful to study the exchange rate as this is an indicator of future inflation as well. A high inflation should be accompanied by depreciation. This is more so if other countries experience lower inflation rates, since it should be the difference between domestic and foreign inflation rates to determine the direction and the scale of exchange rate movements (Piana, 2001).

1.8.3. Housing adjustment theory

In housing consumption activity, there are several available alternatives to the household. When a threshold level of dissatisfaction or stress with the present housing conditions is reached, the household has several options. The adjustment alternatives include making improvements to the existing dwelling, moving to a more suitable dwelling, or moving and then improving the dwelling (Seek, 1983). Seek's reference to housing improvement includes addition, alteration, or renovation to the structure.

The threshold level of dissatisfaction depends on the changes in socioeconomic circumstances and housing attributes. For example, an increase in household size or the aging of children and/or other relatives may trigger a household to construct new housing structure as they require more space to live. Another socioeconomic trigger may be the natural progression through life accompanied by career development and increased wealth; these tend to lead to more housing services as households can afford more (ibid). Ultimately, the decision to alter, extend, or construct a new housing structure may result from varying levels of dissatisfaction with present housing conditions, but is also highly

dependent on the household's financial capabilities (ibid). The benefits of moving must outweigh dissatisfaction and adjustment costs.

1.8.4. Complexity theory

Rather than approaching system behaviour through simplification and analysis or reduction of the whole, complexity science studies how relationships between parts give rise to the collective behaviours of a system and how the system interacts and forms relationships with its environment. Complexity theory has its origins in general systems theory, whose focus in the late nineteenth century was on determining ways in which the elements comprising a system interact with one another through structures that embodied feedbacks, keeping the system sustainable within bounded limits (Batty, 2007).

Complexity theory "conceives of the world consisting of self-organizing systems, either reproducing their existing state via negative feedbacks with their environment or moving along trajectories from one state to another as a result of positive feedbacks" (Blackman, 2000, pg. 141). Emergence is then a process of positive feedback between action and its environment. Properties of a social system are said to be emergent if they result from social combination and have contingent effects, including acting back on the elements from which they arise or emerge (ibid).

Batty (2007, pg. 7) claims that "new complexity sciences are rewriting the theory of general systems, still founded on the [fundamentals] of structures composed of elements, now often called actors or agents, linked through interactions which determine the processes of behaviour which keep the system in equilibrium and/or move it to new states".

1.9. Structure of the report

Chapter 2 provides a review of recent literature on agent based modelling, its applications in urban and regional planning, conceptual models, empirically-derived agent based models, and a short section on modelling informal settlements. Chapter 3provides a detailed description of the methodology used in meeting the research aim. It also discusses the approach used in answering each research question. Chapters 4, 5 and 6 present the results of the analyses and discussion in achieving objectives 1, 2 and 3, respectively. Chapter 4 discusses the micro-level household housing construction activity and location choice, Chapter 5 looks at the macro-level economic performance of the country within specific time periods, while in Chapter 6 the model concept is presented. In addition, Chapter 6 also looks at household level activities for each type of agent as they relate to objective 2. Chapter 7 is a reflection on the methodological approach used in this study. It is a critical review of the research instruments used as well as the means of analysis employed. Finally, Chapter 8 concludes by providing a synopsis of the results of the study, further insight into the usability of the model, and considerations for future work.

2. Modeling agents: a new approach in predicting urban growth

This chapter presents a literature review of different aspects of agent based modelling, its significance in urban planning, and examples of its application in this field. Specifically, this chapter provides a description of the technical aspects of agent based modelling and discusses its relevance in land-use/land cover change prediction. The technical aspects found here are relevant to subsequent discussions of these models, especially in Chapter 6 where the model concept is developed and Chapter 8 where suggestions are made for further recommendations. This chapter also briefly discusses modelling in informal settlements, attempts a definition of a conceptual model, and cites examples of empirically-informed agent based models found in literature.

2.1. Agent based models

Over the last few decades, a range of models of land-use change have been developed to meet land management needs and to better assess and project future land-use and land-cover change in the urban environment. Some types of models used to monitor these processes include equation-based, system, expert, evolutionary, cellular, and agent based models, and statistical techniques (Parker, Manson, Janssen, Hoffmann, & Deadman, 2003). Agent based models (ABMs) have been receiving particular attention for their advantage over other land use modelling methods such as cellular automata in that they can solve some of the problems of addressing individuals' influences in urban systems (X. Li & Liu, 2007). ABMs have the advantage over other models of capturing emergent phenomena, providing a natural descriptive system, and flexibility (Bonabeau, 2002).

ABMs are said to originate from the field of artificial intelligence, which is defined as the study and engineering of intelligent machines capable of performing the same kinds of functions that characterize human thought. It is the study and design of intelligent agents, where these are able to perceive their environment and take actions which maximize their chances of success. Additionally, it is connected to many other fields including complexity science, management science, the social sciences in general, and traditional modelling and simulation (Macal & North, 2006).

2.2. Building an agent based model

Building a computer-based ABM generally requires the modeller to follow certain steps as with any other type of model. These include identifying the purpose and the questions to be answered by the model and engaging the relevant stakeholders in the process. Next, there should be a systematic analysis of the system being studied and identification of the relevant agents, their interactions and the relevant data sources (Macal & North, 2006). Specifically for ABMs, additional requirements may involve the following: "(1) identify agents and get a theory of agent behaviour, (2) identify the agent

relations-ships and get a theory of agent interaction, (3) get the requisite data, (4) validate the agent behaviour models in addition to the model as a whole, and (5) run the model and analyze the output from the standpoint of linking the micro-scale behaviours of the agents to the macro-scale behaviours of the system" (Macal & North, 2006, p. 78). The components of an ABM are agents, the environment within which the agents interact, time steps, and randomness (Gilbert, 2008). Interactions can be in the form of agent-agent or agent-environment. The environment itself can be physical or social (ibid) and can be further described as either static or dynamic. The time step is the length of time it takes for an internal event to occur, after which the system is updated. Randomness accounts for other unpredictable and unexpected agent behaviour which cannot be modelled by the system.

Macal and North list the specific steps for building the computer simulation as follows:

1. *Agents:* Identify the agent types and other objects (classes) along with their attributes.
2. *Environment:* Define the environment the agents will live in and interact with.
3. *Agent Methods:* Specify the methods by which agent attributes are updated in response to either agent-to-agent interactions or agent interactions with the environment. This relates to the methods by which learning is accomplished by the agents.
4. *Agent Interactions:* Add the methods that control which agents interact, when they interact, and how they interact during the simulation. These are specified by the agent behavioural rules set in the design of the model.
5. *Implementation:* Implement the agent model in computational software.

2.2.1. Agents

Many definitions of what an agent is and is capable of doing exist in literature. Gilbert and Terna (2000) define agents as possibly being designed as production systems, comprised of a set of behavioural rules (conditional and actions rules), working memory (allows for learning), a rule interpreter which decides what to do when certain conditions are met, an input process, and an output process. Bonabeau (2002) and Macal and North (2006), citing Casti (1998), define an agent as any independent component of the model which exhibits some form of primitive to complex behaviour, can learn from the environment (adaptive behaviour), or is given base-level rules as well as high-level 'rules to change' rules. They are further described as possessing the following characteristics: perception, performance, memory, and policy (Gilbert, 2008). Macal and North (2006) define the fundamental feature of an agent being its capability to make independent decisions, which require it to be active rather than passive. These authors (ibid) further characterise agents as being identifiable (discrete individuals), situated in an environment, goal-oriented, autonomous and self-directed, and flexible (adaptable). Unlike in typical economic models, agents representing actors can vary in terms of preferences and rules of actions, making them heterogeneous (ibid).

2.2.2. The environment

In ABMs the environment is the virtual world within which the agents exist and interact with each other. It may represent geographical space, thereby deemed spatially explicit, simulating some

graphical feature of a city (Gilbert, 2008). The environment can also correspond to a social space within which the agents interact (Cadman & Twomey, 2002).

2.2.3. Time

In ABMs time is modelled as discrete time steps in which some or all agents are given an opportunity to act in some way depending on the behavioural rules set during the design (Gilbert, 2008). Agent action during each time step may be sequential asynchronous, random asynchronous, or synchronous, all of which suggest that all agents perform some action within each time step. Implementation may also be event-driven, however, where there may be periods of inactivity; thus, the simulation "skips" from one event to another within each time step (ibid). The choice of involving all or just some agents within each time step is dependent on the social phenomenon being modelled.

2.2.4. Randomness

Randomness is introduced into ABMs to account for random variation or "noise" (Gilbert, 2008). Randomness is that feature of the model which considers the unexpected or unpredictable variation in behaviour of the agents. As with other types of models of social phenomena, reality cannot be represented accurately in absolute terms; there persists variation in agent behaviour which may be evident from empirical data.

2.2.5. Agent interactions

Agents interact within the environment in which they are located and can learn from each other through directly passing messages to each other (as in opinion dynamics models) or by observation of other agents (Gilbert, 2008). Communication between agents may be best done by routing through the environment (ibid).The Environment-Rules-Agent Framework described by Gilbert and Terna (2000) represents a structure within which the behavioural rules for each agent type may be written (Figure 2-1**)**.

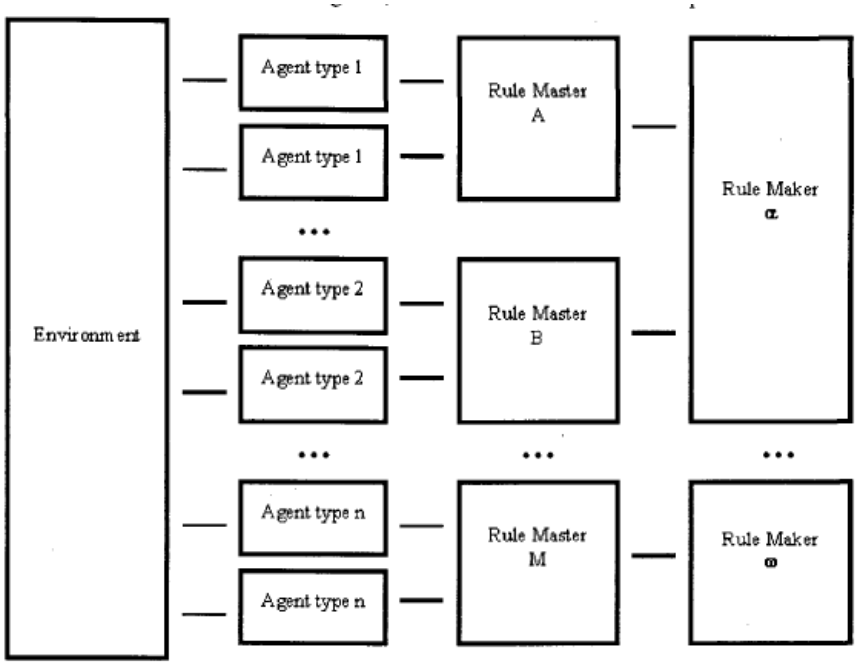

Figure 2-1: Environment-Rules-Agent Framework[2]

2.2.6. Bounded rationality

ABMs provide the means by which to model individuals as possessing a limited degree of rationality. Traditionally, individuals were modelled as being completely rational in their decision-making, particularly in economics where welfare or utility optimization is the ultimate goal. That is, they were perceived as being able to follow and engage in long chains of complex logic and reasoning (Gilbert, 2008). As such, they were said to be "hyperrational". This aspect of rational choice theory has been challenged. As a result, it is proposed that individuals (in this case agents) are modelled as being "boundedly rational", meaning that they are "limited in their cognitive abilities and thus in the degree to which they are able to optimize their utility" (Gilbert, 2008, citing Kahneman 2003; Kahneman, 2003)). Bounded rationality is based on the premise that individuals only have certain information available to them and base their decisions on this limited knowledge.

2.2.7. Learning

Agents have the capacity to gain information (learn) and change their behaviour. Learning can be achieved or modelled in any of three ways: individual by agents' own experience, evolutionary where agents learn because weaker agents die off, or social where agents learn from each other's experiences (Gilbert, 2008). The degree of agents' resemblance to real world entities has been classified by Cadman and Twomey (2002) as low, medium, and high fidelity. Low fidelity suggests the agents are completely abstract and perhaps homogenous in their behaviour. At the other extreme are agents of high fidelity who possess beliefs, intentions and desires of real world entities. These agents may possess the capacity "to adapt and learn, such that the agents' behaviours and properties evolve over

[2] Source: Gilbert & Terna, 2000

time as they learn about their environment and what actions lead to success or failure" (ibid). These agents are said to be "mentalistic" or cognitive.

2.3. Software environments and programming languages

Several software environments and programming languages exist for simulating ABMs. Model representation can be done through the use of Unified Modelling Language (UML) (Fowler & Scott, 1997; Macal & North, 2006; Martin, 1997). Parker, Manson et al. (2003), citing Fowler and Scott (1997), have also suggested the use of UML as ABMs common language for the facilitation of cross-fertilization and comparisons between models. UML is a high-level visual modelling language independent of the Object-Oriented (O-O) programming language commonly used to develop ABMs (Macal & North, 2006). UML is used to specify, visualize, modify, construct and document the artefacts of the O-O software-intensive system under development. Potential O-O languages include Java, C++, and Visual Basic (Gilbert, 2008). Available free modelling software environments include Repast (Recursive Porous Agent Simulation Toolkit), Swarm, NetLogo, and MASON (Multi-agent Simulation Toolkit), among others.

2.3.1. Repast

The ease of simulation building by incorporating Repast's library components into other programmes or by using its visual scripting environments, as well as its free and open source status, renders it one of the most extensively used in social simulation (Macal & North, 2006). There are three production versions: RepastPy for Python, RepastJ for Java, RepastS (Simphony) which is also Java based, and Repast.NET for the Microsoft .NET framework. RepastJ supports large-scale ABMs and includes features such as an event scheduler, model visualization environment, integration with Geographic Information Systems for modelling agents in a spatial environment, and adaptive behavioural tools such as neural networks and genetic algorithms (ibid).

RepastS is a free and open source agent-based modelling toolkit that simplifies model creation and use. It offers a rich variety of features including the following (Argonne National Laboratory, 2008; Synthetic Thought, 2009):

- Fluid model component development using any mixture of Java, Groovy and flowcharts
- A pure Java point-and-click model execution environment
- A fully concurrent multi-threaded discrete event scheduler
- Libraries for genetic algorithms, neural networks, regression, random number generation, and specialized mathematics
- An extremely flexible hierarchically nested definition of space including the ability to do point-and-click and modelling and visualization of 2D environments; 3D environments; networks including full integration with the JUNG network modelling library as well as Microsoft Excel spreadsheets and UCINET DL file importing; and geographical spaces including 2D and 3D Geographical Information Systems (GIS) support;

- A range of data storage "freeze dryers" for model check pointing and restoration including XML file storage, text file storage, and database storage;
- An automated Monte Carlo simulation framework which supports multiple modes of model results optimization;
- Built-in tools for integrating external models;
- Distributed computing with Terracotta;
- Full object-orientation;
- Optional end-to-end XML simulation
- A point-and-click model deployment system; and
- Availability on virtually all modern personal computing platforms including Windows, Mac OS, and Linux.

2.4. Land-use/land cover change ABMs and applications

Various examples of ABMs of land use/land cover change have been developed. Notable examples include a model of exurban township (Dynamic Ecological Exurban Development (DEED)) and a model of an urban system SLUCE's (Spatial Land Use Change and Ecological Effect) Original Model for Exploration (SOME) of a section of Michigan, USA (Brown, et al., 2008). In these models, some of the agents include households, developers, farmers, local government, lending institutions, and the federal government. A wealth of other ABMs of land use/land cover change can be found in d' Aquino, August et al. (2001). Parker, Manson et al. (2003) have also listed a series of agent-based/cellular automata combination models, which *inter alia*, simulate spatial planning, evolution of settlements, and residential location dynamics. Applications of ABMs in the area of land use/land cover change include modelling landscape functions, testing social and economic science concepts, testing hypotheses of land-use and settlement patterns, participatory modelling, and policy analysis and planning (Matthews, Gilbert, Roach, Polhill, & Gotts, 2007), among others.

2.5. Spatial planning support systems

A planning support system (PSS) can be considered any collective set of tools that inform most stages of the technical planning process, which includes problem identification, analysis, generation of alternative plans, evaluation, choice, and implementation (Batty, 2007). Geertman & Stillwell (2004) defines a PSS as consisting of a 'wide diversity of geo-information tools that are dedicated to support public or private planning processes (or parts thereof) at any particular spatial scale and within a specific planning context'. The authors further define PSS as a subset of computer-based geo-information instruments that support the planning process by way of communicating information as well as generating solutions (ibid). SPSSs are system tools that support planning in a spatially explicit context. Sharifi (2007) describes a spatial planning support framework that is coupled with decision-support as these are two parts of the same decision-making process, as it relates to spatial problems (Figure 2-2). It begins with an Intelligence phase where the spatial system is described and the main problems are identified. The intelligence phase is a natural precursor to the Design or planning model

phase. Planning models are build to address the issues addressed during Intelligence and should allow for experimentation and assessment of the system under realistic future scenarios. Alternative plans are evaluated during the Choice phase of the process (Sharifi, 2007).

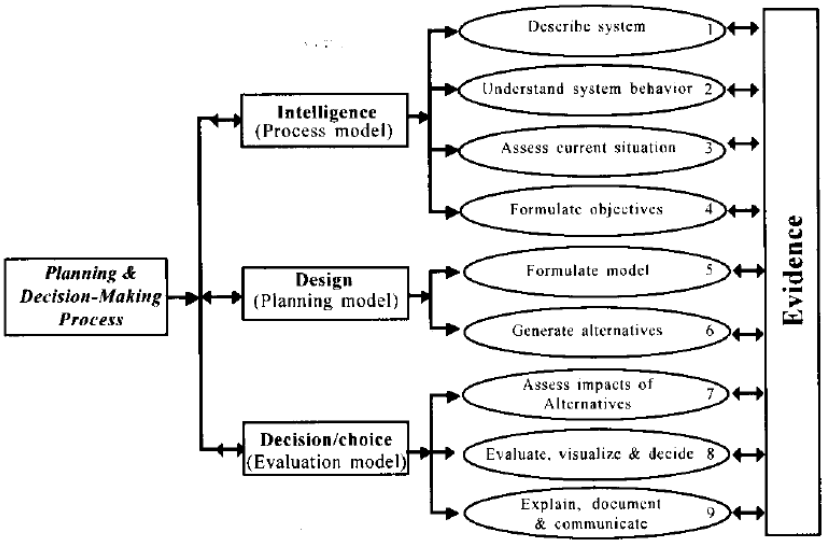

Figure 2-2: Framework for planning and decision-making process[3]

Some SPSSs include *What-If*, *RAMCO* (Rapid Assessment for Management of COastal Zones), *UrbanSim*, and *OBEUS* (Object-based Environment for Urban Systems). Agent-based modelling software packages, as toolboxes of their own, have the advantage of enabling users to develop models which have the generic properties of the application itself (Batty, 2007).

2.6. Modelling informal settlements

While many of the ABMs found in literature model some aspect of the urban environment in various different global locations, less popular has been the modelling of the growth of informal settlements. This is perhaps due to the complex nature of the physical, economic and social processes occurring within the settlements – processes which are highly dependent on biophysical factors and demographic characteristics of the resident population. Sliuzas (1988, p.27) explains that "the growth of a settlement is clearly not a random process and is likely to be influenced by a number of physical, cultural, and economic factors".

An example of an informal settlement growth model can be found in Sietchiping (2004) where the growth of a settlement in Yaounde, Cameroon is simulated by considering physical and socioeconomic influences. This model, however, is based on cellular automaton and incorporates GIS. The author (Sietchiping, 2004) reiterates that limited studies have been conducted that demonstrate

[3] Source: Sharifi 2007

how different factors and theories can be used to simulate and model informal settlements' dynamic growth.

2.7. Definition of a conceptual model

Whereas an ABM implicitly suggests the development of a computer model, a conceptual model, on the other hand, is a model that represents simplified human understanding of real world systems, which is a necessary prerequisite for running an ABM. In meteorology, it is defined as a model which "describes essential features of a meteorological phenomenon and identifies the principal processes taking place" (Geodynamik, 2009); in environmental sciences "[it] is able to represent the current understanding of a process of interest…[and] it can include the relevant components and how they interact in a system that helps to clarify issues, needs and pressures" (Department of Environment Climate Change and Water, 2009); and a simpler definition from the OECD: a model that "represents the human understanding of a system… [it] describes how relevant information is structured in the natural world,.…how the human mind is accustomed to thinking of the information" (OECD, 2006). Sargent (2000) describes the conceptual model as a mathematical, logical, or verbal representation of the system, situation, policy, or phenomenon being studied.

2.8. Conceptual ABM with examples

Considering the definitions of ABMs and conceptual models, in the urban context, the conceptual ABM can be considered a graphical representation of the human perception of the dynamic socioeconomic processes underlying the occurrence or growth of the settlement. It should include all the relevant components and the driving forces and factors, both internal and external, which have the potential to affect the development process and be able to indicate the nature of the effects. The conceptual model should also be able to organize this information in a structured, systematic format for easy translation into a computer-based ABM.

Conceptual modelling is perhaps the most important aspect of any simulation study (Robinson, 2006). The outcome of a simulation study is significantly enhanced by a well-designed conceptual model (ibid). Acknowledging the fact that there is a severe lack of publications on the overall subject of conceptual modeling, Ryan and Heavy (2006) also claim however that the process of developing an accurate process model of a discrete system prior to the development of a simulation model is extremely important.

2.8.1. Multi-agent simulation for urban segregation

The multi-agent simulation for urban segregation (MASUS) is a spatially explicit model that simulates residential location selection in Sao Jose dos Campos, Brazil by analyzing decision-making at the household level based on empirical data (Feitosa, Bao Le, & Vlek, 2009). The model can serve as a tool for exploring "how segregation can be affected by policies that diversify land uses, control land speculation, regularize illegal settlements, promote equal access to basic infrastructure, and stimulate

the construction of developments for middle- and upper classes in poor neighbourhoods. It is also possible to test the impact of adopting social-mix policies, including those focusing on the dispersion of poor families or mixed occupancy as a condition of approval for new developments" (ibid). It consists of three separate modules: urban population (decision-making), the urban landscape, and an experimental factor (Figure 2-3). The urban population module uses a nested logit utility function for decision-making.

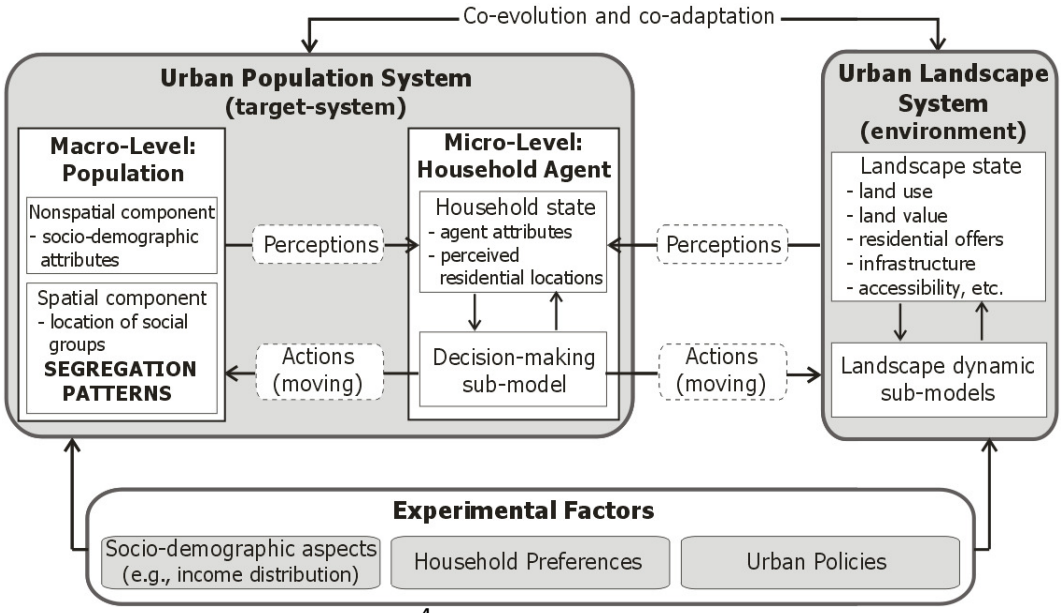

Figure 2-3: MASUS conceptual model[4]

2.9. Empirical basis for ABMs

Empirical information can be used either as input data to a model or as a way to falsify and test a model (Ostrom & Janssen, 2006). There are four main approaches for using empirical information to help confirm patterns observed in ABM (ibid):

1. Use of uncomplicated models of the decisions of simple reactive agents to derive similar statistics as derived from stylized facts, such as the power law distribution;
2. Laboratory experiments to test computational models;
3. Role-play and companion modelling; and
4. Case study analysis.

2.9.1. Problems with case studies

Although case studies are a major research method used extensively by social scientists, when developing an ABM, there may be problems arising from the use of empirical data from case studies. Case studies commonly focus on a specific spatial and temporal scale. Methods used to conduct the

[4] Source: Feitosa, et al., 2009

case study may include archaeological methods, remote sensing, surveys, censuses, interviews, or ethnographic observation (Ostrom & Janssen, 2006). One of the problems associated with case studies is that different causal factors are identified as being important for explaining the processes and outcomes observed (ibid), rendering generalizations difficult. In contrast to theoretical models, empirical ones are often designed to closely match the details of the case study; therefore their conclusions are often specific to that case (d' Aquino, et al., 2001).

2.9.2. Empirically-informed ABMs

Notwithstanding the problems associated with the use of empirical data from case studies, more scholars are using empirical observations to confront their models (Ostrom & Janssen, 2006). Having an empirical basis for the behavioural rules set in an ABM allows the modeller to devise high fidelity agents, meaning they are as close to real world entities as possible. Various recently developed ABMs are informed by empirical evidence. Some examples include an agent-based land market model (ALMA) (Filatova, van der Veen, & Parker, 2008); the MASUS model discussed in Section 2.8.1 (Feitosa, et al., 2009); SimPaSI, which models the relationship between poverty reduction indicators an policy interventions (Smajgl & Carlin, 2009); and an ABM of the relationship between formal and informal rules and their effects on formal institutions called water usage associations (WUAs) (Abrami & Schlueter, 2009).

The ABM simulating the relationship between formal and informal rules and their effects on the WUAs by Abrami and Schlueter (2009) uses the WUAs in Uzbekistan as a case study (Figure 2-4). The conceptual model was set up using field data and expertise. The decision-making rules were established using community-based work and role-playing games. Other components such as formal and informal institutional rules and the external constraints were informed by literature, regulations and official documents.

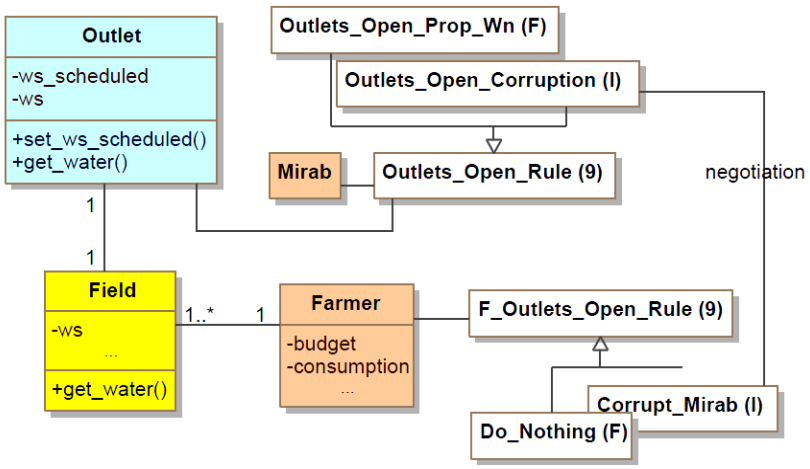

Figure 2-4: Conceptual model of effects of formal and informal rules on WUAs[5]

[5] Source: Abrami & Schlueter, 2009

3. Methodology

This chapter discusses the methodological approach used to answer the research questions set out to meet the main research aim listed below. In order to achieve this, the informal settlement of Hanna Nassif, Dar es Salaam was chosen as a case study. Both qualitative and quantitative methods are used. The main instruments for data collection included a document (literature) analysis and a household questionnaire survey conducted in the study area. Methods used for data analysis vary by the specific research question being answered. The details can be found below.

Aim

The aim of the research is to: **Develop the concept for an agent based model based on the socioeconomic and physical factors influencing the housing construction process in the informal settlement of Hanna Nassif, Dar es Salaam**.

Objectives

1. To analyze micro-level agent decision-making behaviour in residential location and the economic processes which result in housing construction activity
2. To determine the effects of macro-economic conditions and policies which have the potential of influencing agent behaviour in the housing process; and
3. To develop and validate a conceptual model of residential decision-making behaviour of household agents based on the micro- and macro-level driving forces affecting behavioural patterns.

3.1. Research structure

The model concept is built using primarily qualitative data to which some quantitative measures of analysis were applied. There was also secondary qualitative data gathered on macro-economic variables. Spatial data was utilized for analysis in ArcGIS. Figure 3-1 outlines the operational plan under which the study took place. It consists of six phases, including: 1) document analysis (which incorporates: analysis of the growth of informal settlements and a review of macroeconomic literature), 2) collection of socioeconomic and macroeconomic data, 3) analysis and interpretation of data to identify agents and determine agent behaviour 4) structuring of behavioural information, location preferences, and internal and exogenous influences into a conceptual model, 5) model validation using subject matter experts, and 6) presentation of results and further recommendations. Each specific phase is described below. Methods used to answer individual research questions are described in Section 3.2, and are presented in tabular form (Table 3-1).

3.1.1. Document analysis

A document analysis was conducted in order to gain an understanding of two relevant areas of this research: factors impacting the growth of informal settlements and implementation of relevant macroeconomic policy in Tanzania during the development of the settlement of Hanna Nassif.

Analysis of growth of informal settlements

This aspect of the document analysis served to attain an initial understanding of the positive and negative factors affecting the growth of informal settlements in Dar es Salaam as well as other developing country cities. These factors ranged from being economic and social to biophysical in nature. Literature included M.Sc. theses, PhD dissertations, textbooks, and online and printed journal articles.

Review of macroeconomic literature

Literature concerning macroeconomic policies that have impacted micro-level economic behaviour of households was reviewed. Literature included national and international reports and working papers from the World Bank, IMF, and local organizations and universities.

3.1.2. Collection of socioeconomic and macroeconomic data

Primary data was collected by means of household interviews within the informal settlement of Hanna Nassif. The type of data collected at the household level pertained to socioeconomic characteristics, house and plot details, location choice (factors and constraints) and the housing development process. Secondary data on the real effective exchange rate and inflation rate were collected from official reports, working papers and world databases that are prepared, published, or managed under the auspices of recognised institutions and organizations such as the Wold Bank and IMF.

Fieldwork

A total of 40 questionnaires were administered within the study area by two students from Ardhi University in Dar es Salaam, Tanzania. A two-day reconnaissance survey was conducted first to identify fully the study area by use of a map and Geographical Positioning System and also to identify potential respondents for the questionnaire. Respondents were selected on a non-random basis. Due to the lack of temporally adequate remotely sensed and geographic data, the sample was selected on the basis of identification of specific house owners. In this case specificity refers to having been engaged in the housing construction process within certain predefined time periods as well as having some spatial separation between respondent houses. Another requirement made to the interviewers was to select respondents residing nearby the Msimbazi river valley so as to obtain their perception of location choices as well. The students were taken on a walk through the study area by a resident

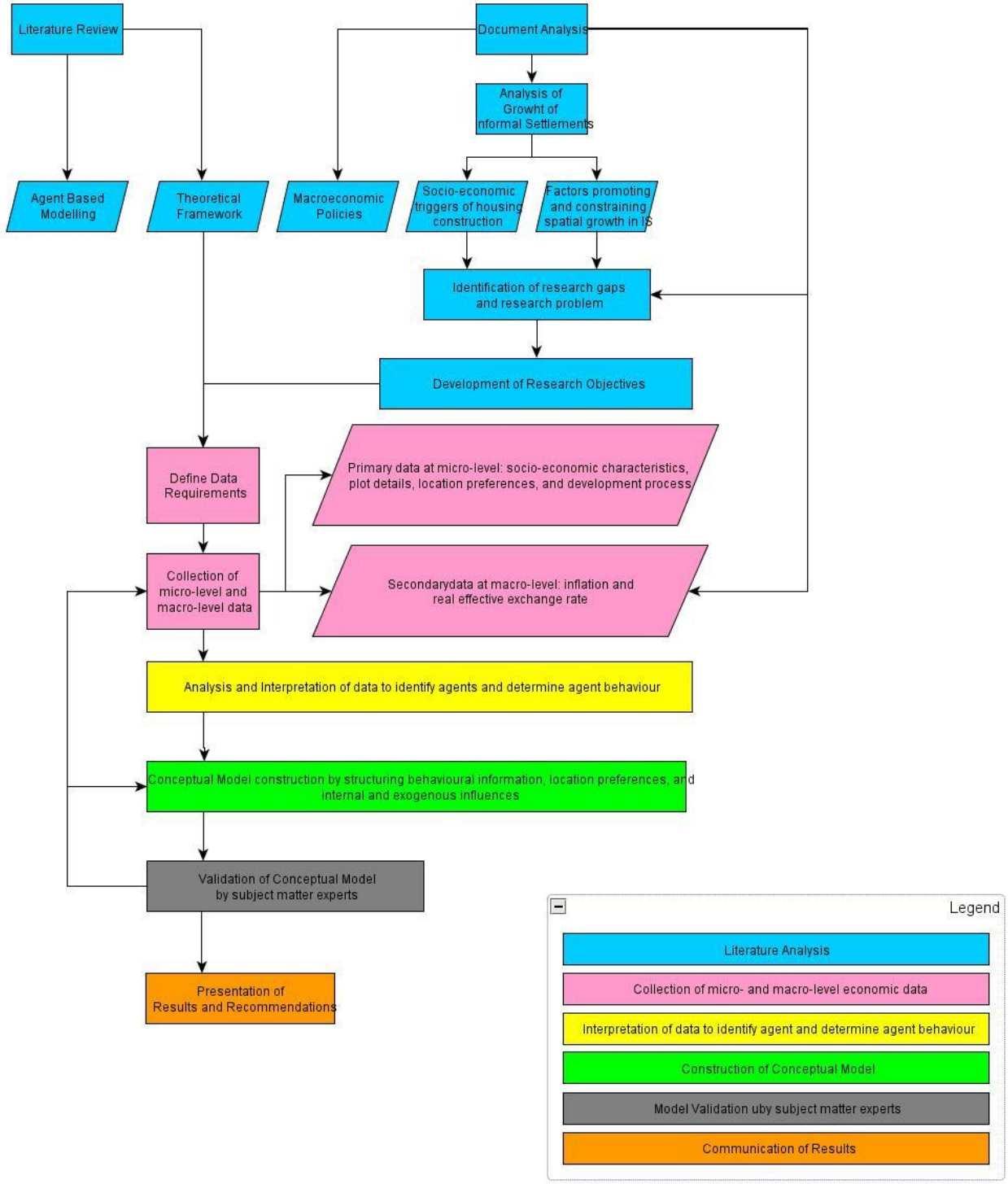

Figure 3-1: Operational Plan

Research Question	Method	Data Required/Prerequisite	Source	Stage in Conceptual Framework		
1.1 What are the socioeconomic factors which trigger housing construction?	Structured household interviews (close-ended questions); literature review; data analysis: frequency, mode	Nominal data on reasons for housing construction; literature	Owner household sample: non-random/quota; textbooks, printed and online journal articles, M.Sc. and PhD theses	LR	CD	AID
1.2 What are the budget constraints for households which are intent on constructing new housing structures**?**	Structured household interviews (open/close-ended questions); literature review; data analysis: mean, median, Kendall's Tau-b statistic	Ratio data (ranges) on sources of finance, income, expenditure, plot and building costs, and saving behaviour; literature	Owner household sample: non-random/quota; textbooks, printed and online journal articles, theses, university web pages	LR	CD	AID
1.3 What are the optimal types of infrastructure and services that determine residential location decision-making**?**	Structured household interviews: (open/close-ended questions); literature review; data analysis: frequency	Ordinal data (ranked) on preferences for particular forms of infrastructure and services and social factors; literature	Owner household sample: non-random/quota; printed and online journal articles, M.Sc. and PhD theses	LR	CD	AID
1.4 What are the constraints that affect location choice?	Structured household interviews: (open/close-ended questions); literature review; data analysis: frequency	Ordinal data (ranked) on physical and natural deterrents to location choice; literature	Owner household sample: non-random/quota; printed and online journal articles, M.Sc. and PhD theses	LR	CD	AID
1.5 What neighbourhood socioeconomic structure favours location choice?	Structured household interviews (close-ended question), literature review; data analysis: frequency	Nominal data on particular structure (e.g. same income, higher income, same occupation, etc.); literature	Owner household sample: non-random/quota; printed and online journal articles,	LR	CD	AID
2.1 What are the historic macro-level economic conditions surrounding the growth of the informal settlement?	Literature review, secondary data collection; data analysis: aggregation (mean) by policy episode (2.2)	Ratio national economic data on real effective exchange rates and inflation rate p.a.	World economic databases and economic outlook reports from World Bank and IMF	LR	CD	AID
2.2 What macro-level policies have been implemented during the historical growth of	Literature review, secondary data collection and analysis	National and international economic reports and working	World Bank, IMF, University of Dar es	LR	CD	AID

the informal settlement?		papers	Salaam			
2.3 How do these macro-level economic conditions and policies affect the housing construction behaviour of household agents?	Structured household interviews (close-ended question); data analysis: summation	Ratio data on number of housing structures built within specific time periods	Owner household sample: non-random/quota	LR	CD	AID
3.1 How can a conceptual model be developed from the information gathered on agent behaviour and its macroeconomic influences?	Literature review; data analysis: categorization of agents via Kendal's Tau-b correlation coefficient; agent attributes for behavioural information derived from questions 1.1 – 2.3; structured household interviews (open-ended questions); Closest Facility network analysis; utility values calculation for each agent type	Literature; information on economic processes and drivers and agents' location preferences, constraints, etc. (above); ratio data on housing costs, construction duration; nominal data on additional agents engaged in location decision-making; road network, local markets, bus stops, slope, flood-prone areas	Analyzed/interpreted data; owner household sample: non-random/quota	LR	MD	
3.2 How can the model be validated to ensure the conceptual model adequately captures the growth of informal settlements and achieves its intended purposes?	Structured/unstructured feedback from subject matter experts (SME's) with knowledge of agent-based modelling and growth of informal settlements in Dar es Salaam	Conceptual Model	Derived	MV		

Note: LR: Literature Review; CD: Collection of micro- and macro-level data; AID: Analysis and Interpretation of data to identify agents and determine agent behaviour; MD: Structuring of behavioural information into agent rules in conceptual model; MV: Validation of conceptual model using subject matter experts

Table 3-1: Research Methods

appointed by the local Mtaa leader. The survey was conducted in the afternoons and evenings of October 28, 29 and 30, and November 2, 3, and 4 2009. Due to inconsistencies in responses obtained from 2 questionnaires, they were removed from those contributing to the analysis of the data obtained. Thus, the sample size is 38 owner households.

Mobility restrictions experienced by the author prevented travel to the study area during the survey administration. In lieu of this fact, there was regular communication with the identified students in the study area, i.e. by telephone and the World Wide Web (specifically email facilities). Prior to carrying out the survey, the students were given written explanation of the intension of each question that was perceived as requiring such explanation. The author was made aware of the interviewers' presence in the field and there was daily feedback on progress of the survey by the administrators. Questionnaires were scanned and emailed to The Netherlands in two parts over a span of two weeks.

3.1.3. Analysis and interpretation of data

The purpose of the analysis of primary and secondary data collected was to identify agents and determine housing construction behaviour and location preferences. Furthermore, the effects of macro-level economic performance and policies on construction behaviour were determined at this stage. To verify the validity of the data received, personal data on income, expenditure, education, and employment were converted to ordinal data and a non-parametric statistical test was carried out. Kendal's Tau-b correlation coefficient was determined for several combinations of variables in a one-tailed bivariate relationship. Running this test also provided a first step toward agent typology for modelling purposes. The Kendal's Tau-b test is adequate for datasets such as the one used in this study because it contains a small sample and a large number of tied ranks. The specific type of analysis applied was dependent on the research question being answered and is discussed in Section 3.**2** and presented in Table 3-1.

3.1.4. Structuring of information into a conceptual model

Agent behaviour and its internal and exogenous influences were structured in a graphical diagram with accompanying description in text. Then, agent behaviour and its influences were structured in a matter that enables easy transformation into a computerized agent-based model. This is explained further in Section 3.2 under research question 3.1.

3.1.5. Model validation using subject matter expert interviews

The initial draft of the conceptual model was validated by third parties called Subject Matter Experts (SMEs), as recommended by the United States Defense Modelling and Simulation Office (2006). This approach is similar to the use of third party entities in the Independent Verification and Validation process described by Sargent (2000). The purpose of the validation exercise was twofold: (1) to determine the fitness of the representation of the individual elements in the model, and (2) to assess the overall capability of the model. Two different types of SMEs were selected based on individual

areas of expertise and experience, i.e. experts with knowledge and experience in the area of growth of informal settlements in Dar es Salaam and individuals with expertise and experience in working with agent based modelling, particularly in the area of land-use change modelling. The details of this stage of the research are discussed in answering research question 3.2 (Section 3.2).

3.2. Answering the research questions

This section describes the method employed to answer the specific research questions.

1.1 **What are the socioeconomic factors which trigger housing construction**?

Socioeconomic factors were derived both from literature and household interviews. An initial list of drivers of construction was attained from a document analysis. This list provided options for a close-ended question within the survey with the option of including additional factors by the respondents (See Annex 1 for questionnaire). Responses were tallied and mode was determined to ascertain the predominant socioeconomic factor. The options included: accommodation of children and other relatives, better access to employment, earn income from rental, to provide a *Madrassa* and to provide own accommodation.

1.2 **What are the budget constraints for households which are intent on constructing new housing structures**?

The set of affordable goods available to households and the budgetary constraints were determined both from literature and household interviews. Literature served to gain a general understanding of the set of available options for the households, while specific percentages of income or other sources of funds spent on consumption bundles were obtained from the interviews via close-ended questions. The purpose of investigating this was to acquire a general idea of the portion of income surplus available for and catered towards housing construction. Respondents were requested to state their average monthly household income and expenditure (given in ranges). The expenditure items included food, water, electricity, education, and other items. Respondents were also asked to state what percentage of income in surplus would be geared toward housing construction. The range and median were obtained from the stated percentages. The median value was then used to derive an equation for the budget constraint of households. Further, the respondents were asked to state what type of construction activity they would engage in with the extra money they have at hand. In order to determine the percentage distribution of owners coming from former tenant households to former owner households, the interviewees were also asked to state whether they were former tenants and their location origins.

1.3 **What are the optimal factors that determine residential location decision-making**?

Literature was used to inform the list of options in close-ended questions in the questionnaire where respondents were asked to rank infrastructure and service factors as well as socioeconomic factors in terms of importance. Interviewees were asked to rank each factor as being not important at all to very important. The different factors expressed as being very important were tallied and

frequencies determined for short-listing of the most important attractive forces. The options included the CBD, industrial area, local market, proximity to planned areas, main road, footpath, school clinic/dispensary, bus route, water pump, mosque/church, family/friends and presence of tribesmen.

1.4 **What are the constraints that affect location choice**?

The same approach was taken in answering this question as in research question 1.3, with the exception that respondents were asked to rank factors they tried to avoid when deciding on a location to reside in. The options included flood prone areas, steep slopes, swamps, riverbanks, noisy bars, and factories. The results were then tallied to shortlist the most important factors that were avoided when choosing a location to settle.

1.5 **What neighbourhood socioeconomic structure favours location choice**?

This question was answered by asking respondents to express explicitly the socioeconomic characteristic of the neighbours among which they prefer to reside. The options included same income, higher income, same occupation, same religion, same education, and same tribe. Results were tallied to determine the predominant neighbourhood characteristics.

2.1 **What macro-level policies have been implemented during the historical growth of the informal settlement**?

2.2 **What are the historic macro-level economic conditions surrounding the growth of the informal settlement**?

Research questions 2.1 and 2.2 were answered simultaneously. First macroeconomic and other related national policies were identified from literature. Policies and their effects on relevant macroeconomic variables were studied, from which different policy episodes of varying effects on Tanzania's national economic performance were singled out. Second, data on macroeconomic conditions was sourced directly from secondary means (Table 3-1). The variables considered for this study included those which have the potential of affecting microeconomic behaviour at the household level. The real effective exchange rate (REER) has shown to be perhaps the most relative price measure at the national level and is a key indicator of external competitiveness of a nation (Y. Li & Rowe, 2007). The REER thus gives an idea of potential changes in price levels within the country. The other variable chosen was inflation rate. Inflation has a direct effect on price levels within the country. Therefore, it affects the household's purchasing power and their resulting saving and construction potentials. Inflation rates p.a. and REER were aggregated to match the individual periods covered by the policy episodes identified under research question 2.1 so as to determine the relationship between policy era and economic performance for the country.

2.3 **How do these macro-level economic conditions and policies affect volume of housing construction**?

The policy episodes identified in research question 2.1 formed the basis for close-ended questions within the household survey relating to particular construction behaviour. Comparisons were then

made of the total number of bedrooms constructed within each policy episode. The result is an estimation of the effects of macro-economic conditions and is thus not quantitative in nature. This information was fed into the model concept.

3.1 **How can a conceptual model be developed from the information gathered on agent behaviour and its macroeconomic influences**?

The data gathered and analyzed was used to construct a conceptual model based on the socioeconomic processes underlying housing construction. Information on socioeconomic characteristics, housing characteristics, location preferences, socioeconomic triggers and construction behaviour were all used to characterize and isolate the different agents involved in housing development. Using the aforementioned information, behavioural rules for each type of agent were developed.

In the household survey, respondents were asked additional questions regarding assistance in the location decision-making process. This was used to identify the types of interactions that took place among the different agents and interactions with the environment. Recommendations were then made for future implementation of a social network in the model, given software capabilities. Information garnered from the macroeconomic section of the study was also used to formulate global parameters/experimental factors for the model.

Although the model produced is conceptual and thus no computer based version was developed, specifications were made on the type of agent utility function to be used as well as specifications for the implementation within a spatially explicit environment. The factors and constraints that contribute to agent utility were specified. Tools used in ArcGIS included the Closest Facility network analysis to determine the nearest bus stop and local market to the settlement. The Near function in ArcGIS was used to calculate the Euclidian distance of each building polygon to these facilities.

3.2 **How can the model be validated to ensure it adequately captures the growth of informal settlements and achieves its intended purposes**?

The conceptual model was validated to ensure its accuracy and adequacy in capturing the growth phenomenon by subject matter experts (SMEs) and its potential for successful implementation. Three SMEs in the area of agent based modelling and 3 with experience in conducting research in Dar es Salaam's informal settlements were requested to participate in the validation exercise. From these, 2 ABM experts validated the model's concept for its technical merit, ensuring that a computer model could result from the information presented in the concept. One informal settlement growth SMEs analyzed the concept in terms of its underlying logic and assumptions, ensuring that it describes and models the growth of these informal areas as understood by him. Validation report questions for each class of SME can be found in Annex 2. A list of the SMEs, their areas of expertise, a list of their publications, and the feedback (some in short version) can

be found in Annex 3. The participants were offered the option of giving feedback in either written or oral form by way of a discussion at their convenience. Each SME responded in written/electronic form via email (World Wide Web).

Feedback comments and recommendations from the SMEs were evaluated for adoption based on four criteria:

1. Ease of implementation
    - Data availability
    - Time necessary for implementation
2. Frequency of occurrence
3. Degree of similarity or relativity to other recommendations
4. No direct conflict with other suggestions/recommendations

Recommendations which did not satisfy criteria 1 above but met criteria 4 and either criteria 2 or 3 were proposed for incorporation prior to implementation of the computer model.

4. Micro-level economic activity and residential location decision-making

This chapter discusses the results of the analysis conducted towards answering the research questions of objective 1. It also discusses the analytical method applied for each question. The section further establishes the foundation for further development of the conceptual model and accompanying agent behavioural rules, which comprise objective 3.

Objective 1: To analyze micro-level agent decision-making behaviour in residential location and the economic processes which result in housing construction activity

RQ 1.1 What are the socioeconomic factors which trigger housing construction?

RQ 1.2 What are the budget constraints for households which are intent on constructing new housing structures?

RQ 1.3 What are the optimal factors that determine residential location decision-making?

RQ 1.4 What are the constraints that affect location choice?

RQ 1.5 What neighbourhood socioeconomic structure favours location choice?

4.1. Triggers of housing construction

Various reasons have been cited for households' engagement in housing construction. Sheuya (2004), in discussing reasons for engagement in housing transformations in Hanna Nassif, mentions building for rental of rooms, accommodation of children and other relatives, provision of working space, and provision of social infrastructure such as a *madrassa* for teaching Islamic religion. He also lists the building of durable houses as an additional factor; however, his investigation included all possible forms of transformation, including improvement of houses.

The socioeconomic factors that contribute to housing construction in the study were determined through household interviews where house owners were asked to specify the reason for building the house they currently reside in. They were given a set of options as well as the option to specify other reasons. The results show that the main reasons for housing construction include accommodation of children and relatives, improve access to places of employment, earn income from rental of rooms, and provision of own accommodation. The most predominant reason for building new housing structures was for accommodation of children and other relatives (Table 4-1). Although the settlement's proximity to the central business district plays an important role in residents choosing that particular location, the main trigger remains accommodation of family members.

Reason for House Construction	No. of Respondents	Percentage (38=100) (%)
Accommodate children and other relatives	27	71.1
Better access to employment	6	15.8
Earn income from rental	4	10.5
Provide own accommodation	1	2.6

Table 4-1: Triggers of housing construction

4.2. Budget constraints and consumption sets

The consumption set is the group of affordable set of goods that is available to any household. The consumption set may only include bundles or sets of goods that would give the consumer at least a subsistence existence (Tian, 2009). Thus, it may include only monthly expenditure (e.g. water, electricity, communication, education, and healthcare), but can be extended to cover other types of irregular expenses, which may include entertainment or clothing, for example. The consumption set is constrained by the financial resources available to the household at any given point. In the case of Hanna Nassif these may be sourced from income, inheritance, retirement benefits, credit, dowry (Sheuya, 2004), or remittances. The budget constraint will then be the combination of goods and services (regular and irregular expenditure) that the household can afford, given the resources available.

First, respondents were requested to state their average monthly household income (Table 4-2) and expenditure (Table 4-3**)**, given in ranges. The list of expense items included food, water, electricity, education, and other items. Given the irregular nature of household income for the self-employed and a composition of 58 % of the working population in Hanna Nassif, respondents were requested to state the nature of their employment (Table 4-4). The options included private, government, self-employment, and unemployment. Unfortunately, the 2 sample units experiencing unemployment were also the ones with grave inconsistencies in the responses and were removed from the sample considered.

Income Range (TShs)	Rank	No. of Respondents	Percentage (38=100) (%)
< 30,000	1	5	13.2
31,000 – 50,000	2	2	5.3
51,000 – 70,000	3	6	15.8
71,000 – 90,000	4	4	10.5
> 90,000	5	21	55.2

Table 4-2: Household income

Expenditure Range (TShs)	Rank	No. of Respondents	Percentage (38=100) (%)
< 30,000	1	5	13.2
31,000 – 50,000	2	9	23.7
51,000 – 70,000	3	8	21.1
71,000 – 90,000	4	3	7.9
> 90,000	5	13	34.2

Table 4-3: Household expenditure

Employment	Rank	No. of Respondents	Percentage (38=100) (%)
Self-employed	1	21	55.3
Private	2	7	18.4
Government	3	10	26.3

Table 4-4: Sources of employment

Second, households were requested to state what percentage of any extra income would be saved for housing construction, as opposed to spending on other irregular items such as entertainment or clothing, for example. A hypothetical amount of TShs 500,000 (the current equivalent of US$375) was proposed for distribution among saving for building, spending on other items, and contribution to community facilities such as road and street maintenance, schools, etc. Percentages were calculated from the responses. The percentages of extra income saved for the purpose of building construction ranged from 0-100 %; the mean was 70.1 %; the median percentage was also 70 %. The type of construction varied from improvement and extension of the current building to construction of new buildings either on the same plot, same settlement or other settlement. The percentage of surplus geared towards communal facilities was very insignificant. Rates ranged from 0-30 %; mean 2.6 %; median 0 %.

Third, in order to ascertain the sources of financial options utilized by households for construction, interviewees were requested to state the source of funding for their own structures. Results are found in Table 4-5 below.

Source of Funding	No. of Respondents	Percentage (38=100) (%)
Savings from income	28	73.7
Savings and loan	4	10.5
Pension	2	5.3
Inheritance	1	2.6
Remittances	1	2.6
Remittances and savings	1	2.6
Loan	1	2.6

Table 4-5: Sources of funding for housing construction

With close to 86 % of the respondents utilizing savings from income or a combination of savings and other sources for housing construction, this is undoubtedly the main source of funding. A small portion of the sample augmented savings from income with a loan, usually from a family member.

The **budget constraint** can then be represented as follows:

$$Income = household\ expenditure + surplus$$

where the surplus is further comprised of 30 % catered toward irregular or chance expenses and 70 % catered for housing construction, written as:

$$Monthly\ Income = household\ expenditure + irregular\ expenses + savings\ for\ housing\ construction$$

Or

$$Savings\ for\ housing\ construction = (monthly\ income - household\ expenditure) \times (0.7)$$

In Dar es Salaam's informal settlements, money saved for housing may be catered toward a variety of activities, including improvement of quality, extension of existing structures, or creating new buildings. New buildings may be built on the same plot, other plot within the same settlement, or another settlement altogether, depending on the budget constraint of the household. Where extension of existing buildings and construction of new ones occur within the same plot or in spaces between existing houses, it is called "infilling" by Sliuzas (1988). Where construction occurs on undeveloped plots in the same settlement or other settlement, it is termed "extension" denoting an extension of the built-up area.

Interviewees were asked to state what construction activity they would engage in with the money they would save for housing. The options included improvement of building, extension of building, and construction of a new building (Table 4-6). For those who opted to construct new buildings they were asked where they would do so. The results are found in Table 4-7.

Type of Activity	No. of Respondents	Percentage (38=100) (%)
Improvement	13	34.2
Extension	14	36.8
New building	9	23.7
n/a	2	5.3

Table 4-6: Construction activities

n/a = not applicable; respondents cater 0 % of savings for housing

A portion of those interviewed (34.2 %) stated they would use the money saved for improvement of the current structure. Noteworthy in this case is that the interviews all already own the house in which

they reside. Tenant household were not interviewed in this survey exercise because they would not have been able to provide much of the information necessary for this study, specifically on physical and financial plot details. Nonetheless, interestingly of those who already own a house, more than 60 % would either further increase in size or construct a new building. Of those who would construct new buildings, most (89 %) said they would do so on another plot for rental purposes; only 1 respondent stated he would construct within the same plot for the provision of his own work space. Head of tenant households naturally only have the option of constructing a new building on an undeveloped plot of land.

Location of new building	No. of Respondents	Percentage (9=100) (%)
Other settlement	6	66.7
Other plot in same settlement	2	22.2
Same plot	1	11.1

Table 4-7: Potential location of new houses

Further information was garnered from the respondents as to whether they had previously been tenants elsewhere in the settlement or in another settlement. The purpose of this information was to obtain information on tenant households, even though they were not interviewed directly. Twenty five of the participants (65.8 %) were previous tenants, originating from various parts of the city and other parts of the country (Table 4-8). One respondent was a tenant in Kampala, Uganda.

Origin	No. of Respondents
Buguruni	1
Hanna Nassif	4
Ilala	1
Kampala, Uganda	1
Keko Mwanga	1
Kimara	1
Kinondoni B	1
Kinondoni Mosille	1
Mabibo	1
Magomeni	3
Manzese	2
Mbagala	2
Mburahati	2
Mwenge	1
Rufiji-Mahenge	2
Ubungo	1

Table 4-8: Origins of tenants in Hanna Nassif

4.3. Optimal factors for residential location

Various physical, social, economic, physical factors (such as infrastructure and services) have been found to attract informal settlement residents to a particular location. Sietchiping (2004), citing Blight and Mbande (1998) lists industrial areas, market places, and transportation networks. The authors further mention that informal settlements tend to flourish in areas along riverbanks, steep slopes, dumping grounds, abandoned or unexploited plots, low lying areas, and wetlands. Berg-Schlosser and Kersting (2003) attribute location attraction to spiritual or religious factors.

In this study, physical, social, religious and economic factors such as the central business district (CBD), industrial area, local market, proximity to planned area, main road, footpath, school, clinic/dispensary, bus route, water pump, mosque/church, family/friends and tribesmen were all considered positive. Respondents were requested to rank each in terms of importance, including not important, somewhat important, important, and very important. Table 4-9 below shows the frequency of responses for factors considered to be very important when households are deciding where to locate themselves.

Factor	No. of Respondents	Percentage (38=100) (%)
CBD	27	71.1
Water pump	20	52.6
Main road	15	39.5
Footpath	12	31.6
Local market	10	26.3
Bus route	10	26.3
Clinic/dispensary	8	21.1
Planned area	7	18.4
School	7	18.4
Mosque/church	3	7.9
Family/friends	3	7.9
Tribesmen	2	5.3
Industrial area	0	0

Table 4-9: Residential location preferences

Respondents were also given the option to state other factors that were important to them. These included proximity to workplace (3) and plot availability (1). It is obvious from the responses that the CBD in this case is the central place for the residents of Hanna Nassif. Dar es Salaam's CBD is the source of employment for many paid wage earners. With close to 45 % of the sample units employed either by private firms or government bodies, it is expected that the CBD would be an attraction for these residents. This result is in line with the socioeconomic survey performed by UCLAS (University College of Land and Architectural Studies) in Hanna Nassif in 1998 where they found that 42 % of the

residents in the settlement were paid wage earners, as opposed to 58 % self-employed (Sheuya, 2004). The presence of water is another important factor for those who have inhabited this area. One resident in particular mentioned the settlement's servicing as the main reason for choosing this particular location. Access to the main road also plays a significant role in location choice. Two respondents attribute their dissatisfaction with the particular plot they were sold to the lack of vehicular access, indicating that some of the residents are mobile.

4.4. Constraints affecting location choice

Kyessi (1990) classifies cliffs, flood plain areas, river banks, low lying areas, and swamps as "bad" land due to their unsuitability for development and finds that only 17 % and 18 % of squatter houses were constructed on bad land in 1975 and 1982, respectively, in Dar es Salaam.

Biophysical factors constraining or deterring household location choice were also ranked by participants in terms of the factors that were very important to avoid when making location decisions. The results are found in Table 4-10 below. Given the option to state other factors, 2 respondents stated oxidation points, 2 mentioned dump sites, 1 mentioned extremely poor neighbourhoods, and 1 church.

Factor	No. of Respondents	Percentage (38=100) (%)
Flood area	35	92.1
High slope	33	86.8
Swamp	24	63.2
Riverbank	22	57.9
Noisy bars	18	47.4
Factories	16	42.1

Table 4-10: Constraints to residential location

Flood areas, high slopes, swamps, and riverbanks were all stated as very important to avoid when looking for a location to reside by the respondents. These constraints to residential location all occurred in more than 50 % of the survey sample.

4.5. Neighbourhood socioeconomic characteristics

Within the set of available and affordable options meeting a households' welfare needs for residential location, there will be certain socioeconomic characteristics of a neighborhood that will drive the household to choose one in particular. Several models have been developed that show how urban segregation occurs over time with regards to income, race or ethnicity, and other factors (Feitosa, et al., 2009; Pollicott & Weiss, 2001).

Household owners were asked to specify the most important socioeconomic characteristic of the resdients with whom they wished to share a neighbourhood when they were deciding on a place to

build. They were asked to choose from same occupation, same religion, same tribe, same education, same income, higher income, or other. The results are found in Table 4-11 below. One respondent menioned he had no choice as the plot on which he build was inherited.

Socioeconomic characteristic	No. of Respondents	Percentage (38=100) (%)
Same income	25	65.8
Same occupation	4	10.5
Same religion	3	7.9
Same education	1	2.6
Same tribe	1	2.6
No choice (inherited)	1	2.6
No response	3	7.9

Table 4-11: Preferred neighbourhood socioeconomic characteristics

More than 65 % of the respondents stated that they would prefer that their neighbours possess similar income as they do. For a very small percentage religion and education are important characteristics.

5. Tanzania's Macroeconomic Policies, Inflation rate and REER

This chapter discusses the results of the analysis conducted towards answering the research questions of objective 2. It starts off by discussing the different policy episodes and accompanying macroeconomic policies implemented in Tanzania during the historic development of Hanna Nassif. During each policy episode the macroeconomic situation is discussed; this includes variables such as real effective exchange rate (REER) and inflation rates. It concludes by analyzing housing construction activity in Hanna Nassif during each policy episode.

Objective 2: To determine the effects of macro-economic conditions and policies which have the potential of influencing agent behaviour in the housing process

RQ 2.1 What macro-level policies have been implemented during the historical growth of the informal settlement?

RQ 2.2 What are the historic macro-level economic conditions surrounding the growth of the informal settlement?

RQ 2.3 How do these macro-level economic conditions and policies affect volume of housing construction?

5.1. Macroeconomic policy and conditions

This section discusses the three main policy episodes between 1970 and 2004 which represent major differences in the performance of Tanzania's macro-economy. It starts off with a period when there was recognition of the need for reform of the administrative approaches and management strategies of central government, followed by a period focused on economic growth and efficiency, and finally a period where both main strategies are combined. During each period or episode, the REER and inflation situation is analyzed at an aggregated level.

5.1.1. 1970-1985: Social policy and inward reform episode

Nineteen seventy to 1978 was the first part of the period of inward reform in which there was an increasing role of the state in the domestic economy and the pursuit of an import-substituting strategy aimed at creating a new brand of African socialism. International donors were supportive and foreign aid reached almost 15 % of the GDP (Y. Li & Rowe, 2007). The average rate of inflation of prices p.a. in the CPI was 10.7 % **(**Figure 5-1; Annex 4**)**. The REER averaged around 105 % of the 2000 REER (Figure 5-2), which in nominal terms was approximately TShs 850 to US$1.

In the second half of this inward reform period, 1979-1985, there was a major decline in commodity prices resulting from external shocks. The prices for cotton, clove and coffee, which at the time

constituted about 57 % of the export revenues, fell by 15 % (ibid). The inflation rate also skyrocketed at an average annual rate of 28.3 %. According to the World Bank (2002a), to deal with the macroeconomic crisis during this period, the government launched two successive "home-grown" stabilization programs: the two-year National Economic Survival Program (NESP) in the 1981 financial year, followed by the three-year Structural Adjustment Program (SAP) in financial year 1982. During this period the REER averaged approximately 154 % compared to the 2000 rate.

The period encompassing 1970-1985 further coincides with what Wangwe and Charle (2005) refer to as the Social Policy Episode in Tanzania's macroeconomic policy choices (1970-1986), in which the major means of production were put under the state, thus resulting in the change aforementioned. In 1986 the Tanzanian Shilling was devalued by more than 50 percent (Y. Li & Rowe, 2007).

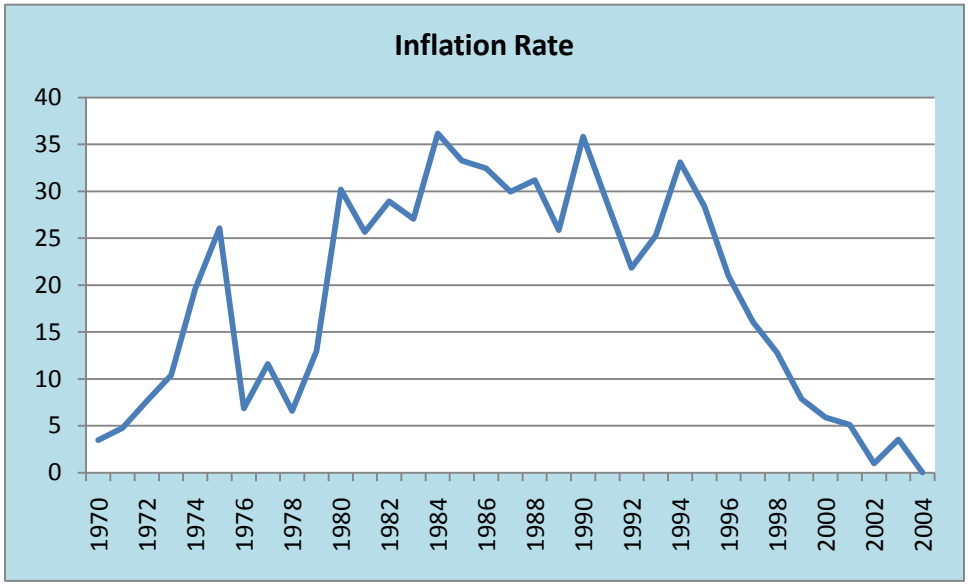

Figure 5-1: Tanzania inflation rates 1970-2004[6]

[6] Source: IMF, 2009; Nation Master: World Development Indicators Database, 2009

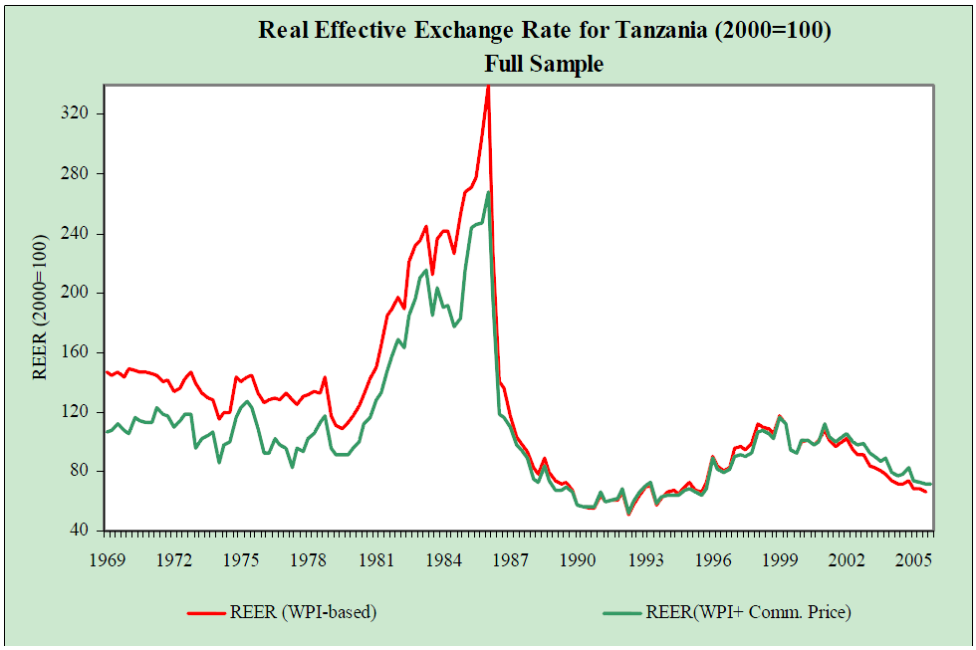

Figure 5-2: Tanzania real effective exchange rates 1969-2005[7]

5.1.2. 1986-1993: Policies for efficiency and growth episode

The period of policies for efficiency and growth was marked by high inflation, budget in deficit, balance of payment in deficit, shortage of goods, and underutilization of productive capacities (Wangwe & Charle, 2005). Two main three-year macroeconomic programs were implemented. The first program (called ERP-I, started in 1986) was aimed at increasing efficiency and restoring economic growth, reducing inflation and fiscal deficits, realigning the exchange rate, and improving the balance of payments by increasing exports and foreign exchange earnings (World Bank, 2002a).

Specific measures taken to achieve the objectives of the program included:

- substantial increases in agricultural producer prices and improvements in marketing structures to provide incentives for increased production of food and export crops;
- devaluation of the local currency;
- reactivation of interest rate policy to attain positive interest rates and thus encourage savings mobilization and their efficient deployment;
- rehabilitation of the worn-out physical infrastructure of the country in support of directly productive activities;
- increase in capacity utilization in industry through the allocation of scarce foreign exchange to priority sectors and firms; and
- reduction of the inflation rate with the aim of bringing it from above 30 percent to less than 10 percent.

[7] Y. Li & Rowe, 2007

The inflation rate (from CPI) declined marginally from about 32.5 % in 1986 to about 30 % by end of the program period in 1988 (World Bank, 2002a). This inability to contain inflation was mainly due to excess expansion of domestic credit, which led to expansion of the money supply beyond planned levels (monetary inflation). Foreign exchange earnings increased slightly, but the exchange rate was steeply depreciated during the financial year 1987 (through devaluing the local currency), by 338 % in nominal terms and 111 % in real terms (Y. Li & Rowe, 2007, citing Sahn, Younger et al. 1999;).

ERP-I was followed by the second program in 1989: Economic and Social Action (ERP-II). The program included many of the objectives of ERP-I but also focused on wider market reforms and consideration of the social aspects of adjustment. Improvements in the growth of the economy recorded under the ERP-I could not be maintained. During this period the inflation rate remain at around 30 % p.a. Only agricultural performance improved somewhat during this time.

By 1987 the REER rose to around 340 % relative to the 2000 REER. It saw a subsequent drop to almost 60 % in1992; the inflation rate also dropped to 21.8 %**.** The improvement during this time was partly due to the promotion of private investment in the economy by providing attractive incentives to prospective investors, both local and foreign (World Bank, 2002a).

The overall average inflation rate between 1986 and 1993, however, remained at approximately 28.9 % p.a., while the REER averaged 92 %, relative to the 2000 REER. Nonetheless, the improvement in REER saw positive results in the inflation rate in the following period.

5.1.3. 1994-2004: Initiatives to combine growth and social policy episode

In order to access the joint IMF-World Bank Highly Indebted Poor Countries debt relief funds, Tanzania's government developed a poverty reduction strategy paper (PRSP) in the mid-1990's (Wangwe & Charle, 2005). Much of the economic recovery and stabilization efforts took place under the guidance and funding of IMF's Enhanced Structural Adjustment Facility (ESAF), whose focus was to consolidate earlier recovery efforts, particularly those aimed at:

- ensuring a stable macroeconomic environment
- efficient resource allocation
- increased production, growth, and poverty reduction; and
- more private sector participation in economic activities

On a whole, the government's role in the economy was reviewed, taking into account the changing economic environment (World Bank, 2002a). There was a significant decline in inflation (Y. Li & Rowe, 2007). The average inflation rate p.a. was about 8.1 %, gradually falling from 20.98 % in 1996 to under 1 % in 2004. The REER also declined to 90 % of the 2000 REER.

5.2. Macroeconomic effects on construction activity

Four main macroeconomic policy episodes were identified in Tanzania's recent history, from 1967 to 2004. Nineteen sixty seven to 1978 represents the first part of the episode of social policy and inward reform in which the mean inflation rate p.a. was 10.7 % and the REER was 105 % relative to the 2000 nominal rate of TShs 850 to the US Dollar. In the second part of this policy episode, the inflation rate rose to 28.3 % p.a. and the relative REER averaged 154 %. Nineteen seventy nine to 1985 marked the policy for efficiency and growth episode where the mean inflation rate p.a. was kept at 28.9 % and the REER was 92 %. Finally, the episode of initiatives to combine growth and social policy ran from 1994 to 2004 and saw an average inflation rate of 8.1 % p.a. and REER of 90 %. The REER is a very good indicator of the efficiency of producing goods within Tanzania, as compared to other trading partner countries (Y. Li & Rowe, 2007). Production efficiency is expected to have an effect on prices of goods within the country, which means that the price of construction materials as well as household expenditure will be affected. Furthermore, the inflation rate has a direct impact on the price levels (Lipsey & Steiner, 1972) within Tanzania; thus, construction materials and household expenditure will also be affected. The purchasing power of the Tanzanian Shilling would be reduced if inflation rises. Rise in inflation is not always accompanied by rise in wages.

In order to determine the extent of construction activity in each of the policy episodes discussed above respondents were asked to specify the number of buildings and bedrooms constructed in each period (Table 5-2). The total number of rooms built by the 38 respondents between 1967 and 2004 was 168.

Policy period	Inflation (%)	REER (2000=100 %)	No. of rooms built	Percentage (168=100 %).
1967-1978	10.7	105	43	25.6
1979-1985	28.3	154	23	13.7
1986-1993	28.9	92	34	20.2
1994-2004	8.1	90	68	40.5

Table 5-1: Construction activity by policy episode

More than 65 % of construction activity took place within the two policy episodes in which the mean inflation rate p.a. was near or less than 10 %. Though the sample taken is relatively small and not entirely representative of the population, it is evident from the data available that an increase in the inflation rate negatively affects the rate of construction in Hanna Nassif.

6. Model Development

This chapter answers the research questions under objective 3. Section 6.1 provides a background for the conceptual model and does not form a part of the model itself. It provides the basis for some of the assumptions and agent behavioural rules that are made for development of the model. Section 6.1 starts with categorizing and identifying agents and follows by answering each research question as it pertains to individual agents. Thus, it provides the information necessary to formulate agent micro-level behaviour and preferences. Section 6.2 describes the model and makes clear the assumptions made and the data limitations for model development. The model concept is presented in its most current version, subsequent to incorporation of suggestions and recommendations from the SMEs during the validation exercise. Section 6.3 lists the suggestions and recommendations made by the SMEs, discusses the criteria for incorporation of these into the model concept, and provides a synopsis of the validation exercise.

Objective 3: To develop and validate a conceptual model of residential decision-making behaviour of household agents based on the micro- and macro-level economic driving forces affecting behavioural patterns

RQ 3.1 How can a conceptual model be developed from the information gathered on agent behaviour and its macroeconomic influences?

RQ 3.2 How can the model be validated to ensure it adequately captures the growth of informal settlements and achieves its intended purposes?

6.1. Household agents and micro-level behaviour

This section provides an overview of household agents and their characteristics based on the research questions pertaining to objective 2 of understanding micro-level behaviour. First, agents are characterized based on their most suitable attribute. Then, each research question under objective 2 is answered as it pertains to agents characterized by form of employment, thereby deducing agent behavioural rules and preferences for the model concept.

6.1.1. Categorizing agents

Primary data on income, education, and employment was obtained from households during the questionnaire survey. Kendall's tau-b correlation coefficient was calculated to determine the strength of the relationship among income, expenditure, and employment. This statistic also served to verify the validity of the data, as there are certain relationships that are expected among these variables. First, because the original data on household income was given in ranges, upper and lower limits and mid-range values were extracted. Next, for all three variables, the values were converted to ordinal data, which is more appropriate for the Kendal's tau-b statistic.

Variable	**Education**		**Employment**		**Income**	
	Kt	Sig.	Kt	Sig.	Kt	Sig.
Education	1		.618	.000	.404	.002
Employment	.618	.000	1		.429	.002
Income	.404	.002	.429	.002	1	

Kt = Kendal's tau-b correlation coefficient; Sig. = significance (one-tailed)

Table 6-1: Correlation values for income, education, and employment

As can be seen from Table 6-1 above, there is a strong positive relationship between the type of employment and the level of education, $r = .618$, p (one-tailed) $<.01$, as well as a medium positive relationship between type of employment and income estimate, $r = .429$, p (one-tailed) $<.05$. Thus, categorizing agents by any of these variables would be useful. However, income was not chosen due to the lack of declaration of true income, which was observed by the inconsistencies in stating income, household expenditure, and number of tenants within each owner/tenant house. This notion of failing to declare true incomes is common for residents in Dar es Salaam's informal settlements (Kironde, 1995). It was further noted from data by visual inspection that respondents possessing a secondary school diploma had mixed ranges of income and expenditure ($r = .384$, p (one-tailed) $<.05$). Ultimately, source of employment is the variable which most consistently correlates with the other variables in question. Form of employment was therefore chosen as the method of categorization of agents.

Preliminary analysis conducted regarding behavioural patterns by type of employment showed that housing construction behaviour and residential location preferences for government employees are similar to that found in private firm workers. In other literature, these are both grouped as paid wage earners or residents having formal employment. Therefore, the results for government and private employees are presented jointly in the following sections. There were a total of 17 paid wage earners and 21 self-employed survey respondents.

6.1.2. Triggers of housing construction

Table 6-2 below shows that for both groups the main factor triggering housing construction is the accommodation of children and other relatives. This may be attributed to the natural increase in family size or the maturing of young children.

Reason for House Construction	Formally employed	Self-employed
Accommodate children and other relatives	10	17
Better access to employment	4	2
Earn income from rental	2	2
Provide own accommodation	1	0

Table 6-2: Socioeconomic triggers of construction

From those interviewed, the average family size for those with formal employment was 5, while for the self-employed it is 8. This includes all children and relatives within each household.

6.1.3. Budget constraint

The general budget constraint for residents in the study area was found to be:

Savings for housing construction = (*monthly income – household expenditure*) x (0.7)

where 0.7 represents the portion of the income surplus that would be catered toward new or improved housing. In this equation, about 37 % of the respondents would extend the current structure, while approximately 24 % would construct an entirely new building.

Tenant households would only have the option of constructing new structures. For this reason, respondents were requested to state whether they had previously been tenants in Hanna Nassif or other settlement. Of those with formal employment, 13 (77 %) were former tenants; of the self-employed, 12 (57 %) were tenants prior to building. It is therefore assumed that the remainder of the sample units originated from owner households, being either children or other relative to the original house owner. The income ranges for respondents who are former tenants can be found in Table 6-3; expenditure ranges are found in Table 6-4. From these tables it is clear that most paid wage earners enjoy higher income and, thus, expenditure brackets, while that of self-employed heads of households are more mixed.

Income Range (TShs)	Formally employed (n=13)	Self-employed (n=12)
< 30,000	0	1
31,000 – 50,000	1	1
51,000 – 70,000	1	3
71,000 – 90,000	1	2
> 90,000	10	5

Table 6-3: Income range for former tenants by employment

Expenditure Range (TShs)	Formally employed (n=13)	Self-employed (n=12)
< 30,000	1	0
31,000 – 50,000	4	4
51,000 – 70,000	1	2
71,000 – 90,000	0	2
> 90,000	7	4

Table 6-4: Expenditure range for former tenants by employment

The source of finance for housing construction can be found in Table 6-5 below. It shows that savings from income remains the main source of finance for housing construction in both groups. Those with formal employment claim to save a smaller percentage of their income for housing than the other group: 64 % and 70 %, respectively.

Source of finance	Formally-employed	Self-employed
Savings from income	13	16
Savings and loan	3	0
Pension	0	2
Inheritance	0	1
Remittances	1	0
Remittances and savings	0	1
Loan	0	1

Table 6-5: Sources of funding by employment

Type of Activity	Formally-employed	Percentage (%) n=17	Self-employed	Percentage (%) n=21
Improvement	5	29	8	38
Extension	6	35	8	38
New building	4	24	5	24
n/a	2	12	0	0

Table 6-6: Construction Activity by source of employment

For existing owner households there is still the desire to construct new buildings or extend the current structures in which they reside. Table 6-6 shows the specific construction activity each group would engage in with money saved for further housing.

Assuming that the percentage expressed as saved now would be the same as that saved prior to plot purchase and commencement of construction, the budget constraint for each group can be represented in the manner below.

Budget constraint for extension/new building by tenant households

For the formally-employed heads of households:

$$\textit{Savings for housing construction} = (\textit{monthly income} - \textit{household expenditure}) \times (0.64)$$

Or

$$\textit{Housing cost} = \textit{lot price} + \textit{construction cost} = (\textit{monthly income} - \textit{household expenditure}) \times (0.64) \times (21)$$

Where 21 is the number of months it takes for completion of the housing structure.

And for the self-employed heads of households:

$$\textit{Savings for housing construction} = (\textit{monthly income} - \textit{household expenditure}) \times (0.7)$$

Or

$$\textit{Savings for housing construction} = (\textit{monthly income} - \textit{household expenditure}) \times (0.7) \times (24)$$

Budget constraints would be the same, with the exception that the proportion of owner households engaging in new housing development would differ greatly from tenant households who are enduring a higher amount of 'stress' from current housing conditions.

Lot prices

Respondents were asked to select from a number of ranges within which the price paid for their lot falls. This question was only answered by 30 respondents, i.e. 16 paid wage earners and 14 self-employed residents. They were also asked to state the year in which the lot was purchased. The years varied substantially between 1967 and 2002. Using maximums, minimums, and centre values, the lot prices were converted to US Dollar amounts via real effective exchange rates to determine land value, disregarding inflation rates. In Dollar terms, lot values for the formally employed ranged from $54 (present value TShs 72,000) to $435 (TShs 580,000), having a mode of $390 (TShs 520,000) and median of $286 (TShs 314,000). For self-employed residents, the lot prices ranged from $34 (TShs 45,000) to $455 (TShs 606,000), the modes were $34 (TShs 45,000) and $62 (TShs 82,500), while the median lot price was found to be $74 (TShs 98,500). Figure 6-1 shows fluctuations in lot values over time. The drastic jump in 1987 is due to the corresponding radical fall in inflation rates and associated real effective exchange rate during this time. As a result, while the lot price itself may not have increased drastically, the monetary value had increased.

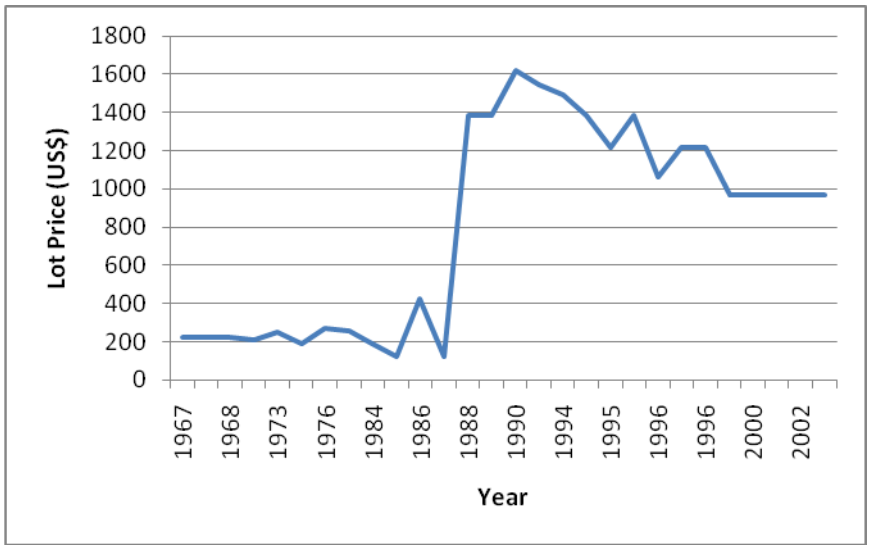

Figure 6-1: Changes in lot values using REER (adjusted to disregard inflation)

The general higher lot prices paid, and corresponding income and expenditure ranges expressed, by the paid wage earners show that these residents earn more, may spend more but also save more (not in percentages but in monetary amounts) and thus are able to afford more pricey lots. Higher prices can be assumed to reflect increased agent utility associated with each location, meaning that these residents are able to acquire the locations they desire in terms of infrastructure and service preferences. It can also be assumed that the higher lot prices occur in those locations that have easier access to the CBD, i.e. lesser travel time to the CBD; however, very little difference in lot price would be observed in Hanna Nassif as a result of proximity to CBD as the settlement covers a small geographic area and is located relatively close to the CBD (4.5 km approximately).

Building costs

An attempt was made to obtain information from the respondents on the cost of construction of their houses. The approach taken was to ask how much each would spend on constructing a 3-bedroom, 1-kitchen, 1-living room house at present day. The expectation is that this figure would give an indication of how much was spent on the individual structures, given the year or years of construction. The responses ranged from TShs 6 million to TShs 20 million from government and private workers; both the median and mode was TShs 14 million. For the self-employed, on the other hand, the prices ranged from TShs 6 million to TShs 17 million; the median and modal price was TShs 10 million.

Using the abovementioned values along with real effective exchange rates, house sizes and different years of construction, the estimated cost of building each sample house was calculated in Dollar equivalents. The mean original cost of houses built by the paid wage earners is approximately US$11,100, while that of the self-employed is US$8,100. The average estimated cost of each habitable room for the former group is US$1,850; for the latter group it is US$1,160.

As can be seen in the difference in lot prices, the formally-employed group generally earn more, may spend more but also save more (not in percentages but in monetary amounts) and thus are able to

afford higher valued houses. These prices may reflect higher quality building materials and not larger house size as one may assume. This group of residents usually build, on average, smaller houses than do the self-employed and have a smaller household size of 5, as opposed to the 8 in the households headed by the self-employed.

Duration of construction

With regards to the size of the housing structure, the average number of habitable rooms for the formally employed was found to be 5 and for the self-employed it was 6, this includes a kitchen and a living room space. From the primary data collected, a total of 102 habitable rooms were constructed by the formally employed and 142 were built by self-employed residents. The duration of construction was given by year. From this data it was deduced that the formally employed group generally build about 2.6 habitable rooms per year. The other group builds about 2.8. Since these values are estimates based on a sample that may not be representative of the entire population and due to their relative similarities, they can be assumed to be the same for both groups. Therefore, it is assumed that on average all households take an average or estimate of 2 years to complete their housing structures.

6.1.4. Optimal factors for residential location

Residents with formal employment have an obvious preference for locations serviced by water, as well as those close to the bus route and the main roads, implying the need for access to public transportation and road and water infrastructure (Table 6-7). For the self-employed, on the other hand, water is an important factor, but also proximity to the local market and the main road. The CBD is a very important factor and is perhaps the main reason why people choose this particular settlement. It is located less than 5 km from the CBD.

Factor	Formally employed	Self-employed
CBD	12	15
Water pump	7	13
Main road	5	10
Footpath	4	8
Local market	0	10
Bus route	6	4
Clinic/dispensary	2	6
Planned area	3	4
School	2	5
Mosque/church	1	2
Family/friends	1	2
Tribesmen	0	2
Industrial area	0	0

Table 6-7: Location preferences by employment

6.1.5. Constraints affecting residential location

The results in Table 6-8 below show that paid wage earners would like to avoid practically all the biophysical and physical constraints listed, paying particular attention to flood prone areas and swamp land. Additionally, two residents mentioned they tried to avoid churches and neighbourhoods with extremely poor people. The other group pays particular attention to flood prone areas and high slopes. For both groups riverbanks are avoided as much as possible, but not as much as flood areas, steep slopes, and swamps. This is an indication that although land with low development capacity is not the first choice for most, they are willing to settle for these as long as they are not likely to flood.

Factor	Formally employed	Self-employed
Flood area	15	20
High slope	14	19
Swamp	15	9
Riverbank	12	10
Noisy bars	12	6
Factories	11	5

Table 6-8: Location constraints by employment

6.1.6. Neighbourhood socioeconomic characteristics

Utility and cost are both determining factors affecting the precise location a potential resident may choose to build a new house. From those available, however, the resident may make his or her decision based on the socioeconomic make-up of the neighbourhood. From Table 6-9 below it can be seen that paid wage earners have a preference for neighbours with similar income and, to a lesser extent, the same occupation. The self-employed, however, prefer to reside among those earning similar income.

Socioeconomic characteristic	Formally employed	Self-employed
Same income	8	17
Same occupation	4	0
Same religion	3	0
Same education	1	0
Same tribe	0	1
No choice (inherited)	0	1
No response	0	2
Other	1	0

Table 6-9: Preferred neighbourhood socioeconomic characteristics by employment

6.2. The model concept

Figure 6-2 shows an overview of the model concept that is based on the data gathered and interpreted from this study. The diagram is comprised of two main levels (micro and macro) and also shows the interaction between global parameters and the micro-level elements.

At the micro-level, there are two modules which detail the actions taken by household agents when intending on constructing houses. The agent transformation module models the transitions of the agent in terms of the attributes they possess, such as tenure and number of children. The decision-making module details the steps taken when an agent is seeking a plot on which to construct a house. The modules culminate in the household agents settling. The combined effect of settling is the macro-level emergent growth of the settlement. The micro-level section of the model is fed and manipulated by global parameters. The overview also shows how the settling of agents affects the characteristics of the spatial environment which in turn affect decision-making and ultimately the spatial growth pattern of the settlement. This feedback mechanism is important for the proper modelling of the system.

6.2.1. Model's agents

Hanna Nassif is one of many informal settlements resulting from the attempted enforcement of ill-conceived statutory planning instruments such as master plans, which made little provisions for the native Tanzanians (Sliuzas, et al., 2004). In an informal setting such as this, understanding individual behaviour forms an intricate part of understanding settlement dynamics; thus agent behaviour forms the core of the model. An ABM is therefore applicable in this case due to the fact that it takes the agent perspective first and foremost (Macal & North, 2006). Under the classification of Cadman and Twomey (2002), household agents will possess high fidelity in that the beliefs, desires, and intentions of their real world counterparts will be modelled as much as possible.

Owner households were found to be arising from both tenant households and existing owner households. Also, there is a clear difference in behaviour between the formally employed and the self-employed heads of households. Differences pertain to location preferences and constraints, and other characteristics such as household threshold size, lot price ranges, and house size (number of habitable rooms) (Table 6-10). The information on agent characteristics and preferential factors is obtained from the household survey conducted.

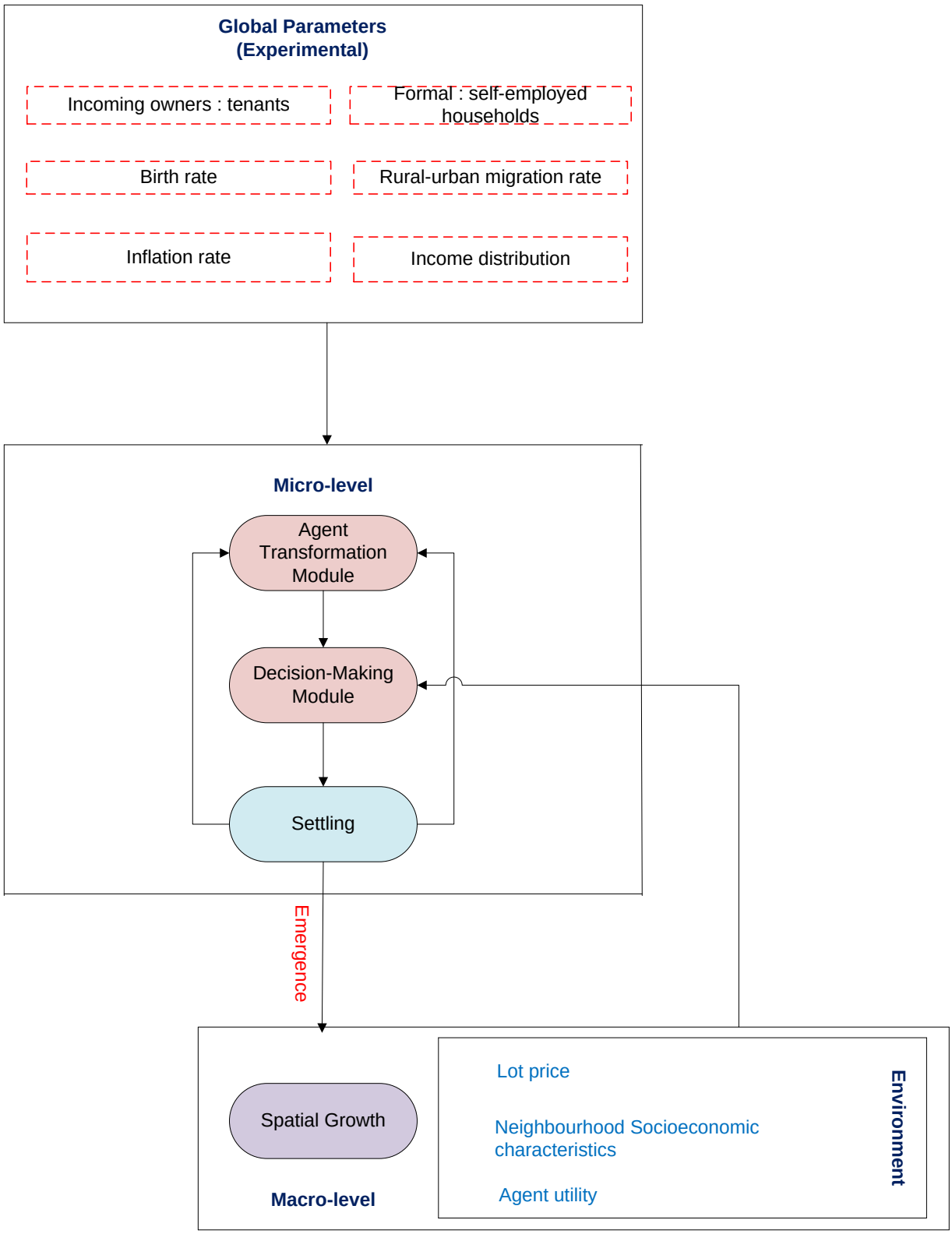

Figure 6-2: Overview of conceptual model

Characteristic	Formally employed tenant or owner agent	Self-employed tenant or owner agent
Preferential factors	Water, roads, bus stop	Water, roads, local market
Constraints	Flood area, steep slope, swamp	Flood area, steep slope, swamp
Threshold number of children	3	6
Typical house size[8]	$60m^2$	$70m^2$
Relative lot price	Medium to high	Low to medium
Preferred neighbourhood socioeconomic characteristic	Similar income and occupation	Similar income
Relative agent utility	High	High

Table 6-10: Agent characteristics

Formal employment refers to either government jobs or employment from private firms. These sources were also found by Hakuyu (1995) in his socioeconomic survey of 5 informal settlements in Dar es Salaam. Sheuya (2004) couples these categories as 'paid wage earners'. Self-employment in Hanna Nassif can be in the form of retail trade and commerce, vending, services and other activities, craft/manufacturing, or construction (ibid). Income is given in relative terms due to the reputation of residents in informal areas of not expressing true income (either deliberately or because the sources vary such that individuals cannot recollect with certainty total monthly income) in socioeconomic surveys (Kironde, 1995). Thus, the quantitative data on absolute values for this variable is not available. The ratio of low/medium/high income earners used is 14:8:3 (56:32:12). This is garnered from the expenditure ranges stated in the aforementioned 1998 socioeconomic survey by UCLAS where 56 % spend between TShs 10,000 and 70,000; 32 % between 71,000 and 130,000 and 12 % spending more than TShs 130,000 per month. Kironde (1995) has suggested that expenditure may be a more realistic indication of true income. Owing to the notion that most people in Dar es Salaam's informal settlements spend most of what they earn (ibid), it is expected that expenditure is highly reflective of true income. In a 1993 survey of 462 individuals, 76 % claimed that they are not able to save any money (Kironde, 1995). The cut-off values were chosen as the percentages somewhat coincide with the same stated low, medium and high income ranges: 67 %, 25 %, and 8 %, respectively. Tenure refers to the agent being either a tenant or owner household. Family size refers to the size of the family, including parents and all dependents (though for modelling purposes 'dependents' are given the same characteristics as children, i.e. they are added to the household at the same rate).

Based on this classification, four main agents were identified:

1. **Tenant households with formal employment**,

[8] Sliuzas (1988), **based on findings by Karlsson (1980)**, estimated a square area of 12 m^2 per habitable room, rendering a typical house size of 60 m^2 and 70 m^2, respectively

2. **Owner households with formal employment**,
3. **Self-employed tenant households**, and
4. **Self-employed owner households**.

Additionally, the building polygons are proposed for modelling as fixed or immobile agents with dynamic attributes (see Section 6.2.4). Thus the vacant and developed building polygons are identified as additional agents:

5. **Building polygons**

Agent Interactions

Interactions take place between household agents and polygon agents of the environment where household agents settle on the building polygons and attributes such as agent utility, lot price, agent income range, tenure, and nature of employment are changed as polygons are developed. These attributes further affect how incoming household agents will interact with these building polygon agents (the environment) (Figure 6-2). This reflects the feedback mechanism between the environment, which represents the physical aspect of the larger (global) system, and the settling of household agents.

6.2.2. Micro level

At the micro-level, there are 2 modules: the Agent Transformation module and the Decision-Making module. At this level an attempt is made to derive the stochastic elements that result in the range of outcomes for agent behaviours and interactions, which is the approach typically used in ABMs (Macal & North, 2006).

Agent transformation module

The **agent transformation module** (Figure 6-3) holds agent states and contains information used to determine when the agent is ready to enter the **decision-making module**. The attributes or variables such as form of employment, income, tenure status, and number of children collectively comprise the agents' state (Table 6-11). As an example, an agent starts off as a starter tenant household having a household size of 2. As the family size increases the level of psychological "stress" (Seek, 1983) also increases so the household begins saving for own housing. When the threshold number of children of 6 is reached (Table 6-10), the agent is triggered to enter the **decision making module**; the agent seeks a plot on which to construct a house. The actions of extending structures and building second structures on the same plot are also triggered by the agent information stored in this module; these are presented as probabilities in the steps below.

Variable	Description
Employment	formal or self-employment
Income	relative (ordinal data); can be low, medium, or high
Tenure	tenant or owner
Number of children	from 2-8; probability of increasing depends on birth rate specified by user

Table 6-11: Agent attributes for agent transformation module

Below are the set of actions that are triggered by the agent transformation module that do not involve decision-making as described in the **decision making module**.

1. **There is a 0.06 probability that an existing owner household agent with formal employment will extend the current structure by adding 3 more habitable rooms, 36 m^2 total**. The 0.06 probability is obtained from the stated 35 % chance divided by an assumed 18 year maturation age before the need arises to extend, multiplied by the 3 children existing in the household (0.35 / 18 x 3 = 0.06).
2. **There is a 0.01 probability that an existing owner household agent with formal employment will build a 36 m^2 (or 3 habitable rooms) house on the same plot**. The 0.01 probability is obtained from the stated 5.9 % chance divided by an assumed 18 year maturation age before the need arises to build, multiplied by the 3 children existing in the household (0.059 / 18 x 3 = 0.0098).
3. **There is a 0.13 probability that an existing owner household agent with self-employment will extend their current structure by adding 3 more habitable rooms, 36 m^2 total**. The 0.13 probability is obtained from the stated 35 % chance divided by an assumed 18 year maturation age before the need arises to extend, multiplied by the 6 children existing in the household (0.38 / 18 x 6 = 0.13).
4. **There is a 0.02 (birth rate / 100) probability that a household will have a child**. The family size attribute is updated.
5. **Formally-employed tenant households with 3 children enter the decision making module.**
6. **Self-employed tenant households with 6 children enter the decision-making module.**

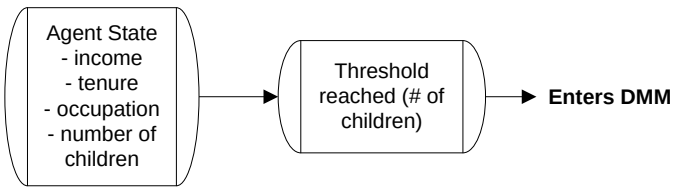

Figure 6-3: Agent transformation module

Decision-making module

From the set of available location options, the agent perceives the environment and chooses the polygon with the highest utility value, within its budget constraint, and where the neighbouring residents have similar income and/or occupation. This choice is made possible through the attributes provided for each polygon within the environment (See Section 6.2.4). If the necessary conditions are met in any of the plots found available then the agent purchases the plot and commences construction. If the conditions are not met, then the agent goes through the cycle again. The number of iterations allowed at each time step will depend on the volume of construction expected and will be determined when the computer model is calibrated.

The owner household develops as the children become older and eventually require more space. Here they have two options: they can either extend the current structure or commence building a new one. If a new house is built, this signals the start of a new household. There is a 35 % chance (0.35) that the formally-employed owner household agent would extend the current structure by supplementing additional rooms. The typical quantity found for this agent was 3 habitable rooms. There is also an 11.8 % (0.12) chance that the owner household would choose to construct another building in another settlement, a 5.9 % (0.06) chance of constructing a house on the same plot, and a 5.9 % (0.06) chance they will construct a building on another plot within the same settlement. If a new plot is sought, then the process of finding an available plot ensues.

For the self-employed owner household agent, there is a 38 % chance (0.38) of extending the current structure. Like with the formally-employed, the typical quantity found was also 3 habitable rooms. There is a 19 % (0.19) chance that the owner household would choose to construct another building in another settlement and a 4.8 % (0.05) chance it will construct a house on another plot within the same settlement. If a new plot is sought, then the process of finding an available plot with the assistance of someone within the relative/friend social network proceeds.

At each time step of the model, the following shall occur:

1. **Formally-employed agents triggered by agent transformation module** seek plots to build on according to rules set in **Figure 6-4** and start building a house 60 m^2.
2. **Self-employed agents triggered by agent transformation module** seek plots to build on according to rules set in **Figure 6-5** and start building a house 72 m^2.
3. Incoming **potential owner** household agent with **self-employment** seek plots to build on according to the rules set in **Figure 6-5** and start building a house 72 m^2.
4. Incoming **potential owner** household agent with **formal-employment** seek plots to build on according to the rules set in **Figure 6-4** and start building a house 60 m^2.
5. **There is a 0.01 probability that an existing owner household agent with formal employment will build a 60 m^2 (or 5 habitable rooms) house on another plot in the same settlement**. The 0.01 probability is obtained from the stated 5.9 % chance divided by an assumed 18 year maturation age before the need arises to build, multiplied by the 3 children

existing in the household (0.059 / 18 x 3 = 0.0098). Agents follow the rules of behaviour found in **Figure 6-4**.

6. **There is a 0.02 probability that an existing owner household agent with self-employment will build a house 72 m^2 (or 6 habitable rooms) on another plot in the same settlement**. The 0.02 probability is obtained from the stated 4.8 % chance divided by an assumed 18 year maturation age before the need arises to build, multiplied by the 3 children existing in the household (0.048 / 18 x 6 = 0.016). Agents follow the rules of behaviour found in **Figure 6-5**.
7. New owner agents' **tenure status is updated** in the agent transformation module.

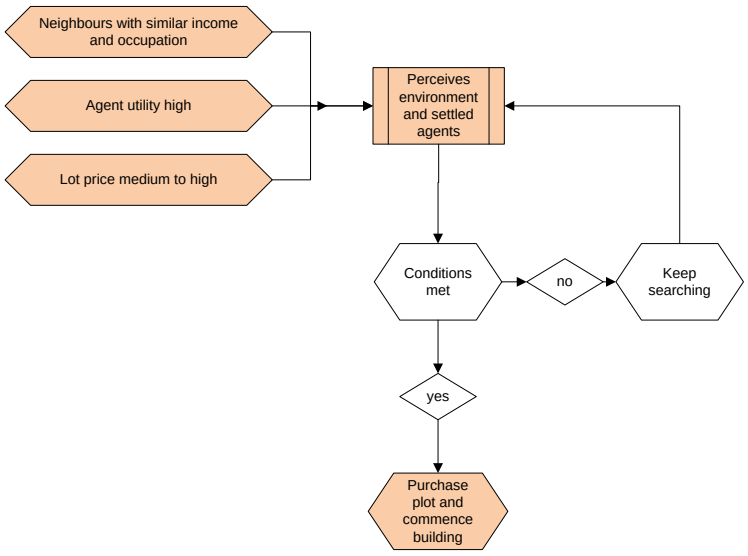

Figure 6-4: Decision-making rules for agent with formal employment

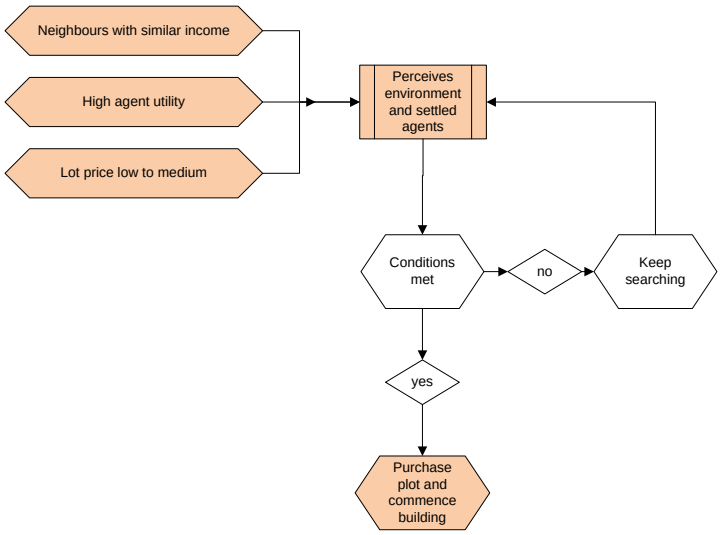

Figure 6-5: Decision-making rules for agent with self-employment

Figure 6-6 shows how the 2 modules in detailed form relate and feed into each other. It also shows where the option to extend current structures by agents takes place within the modules.

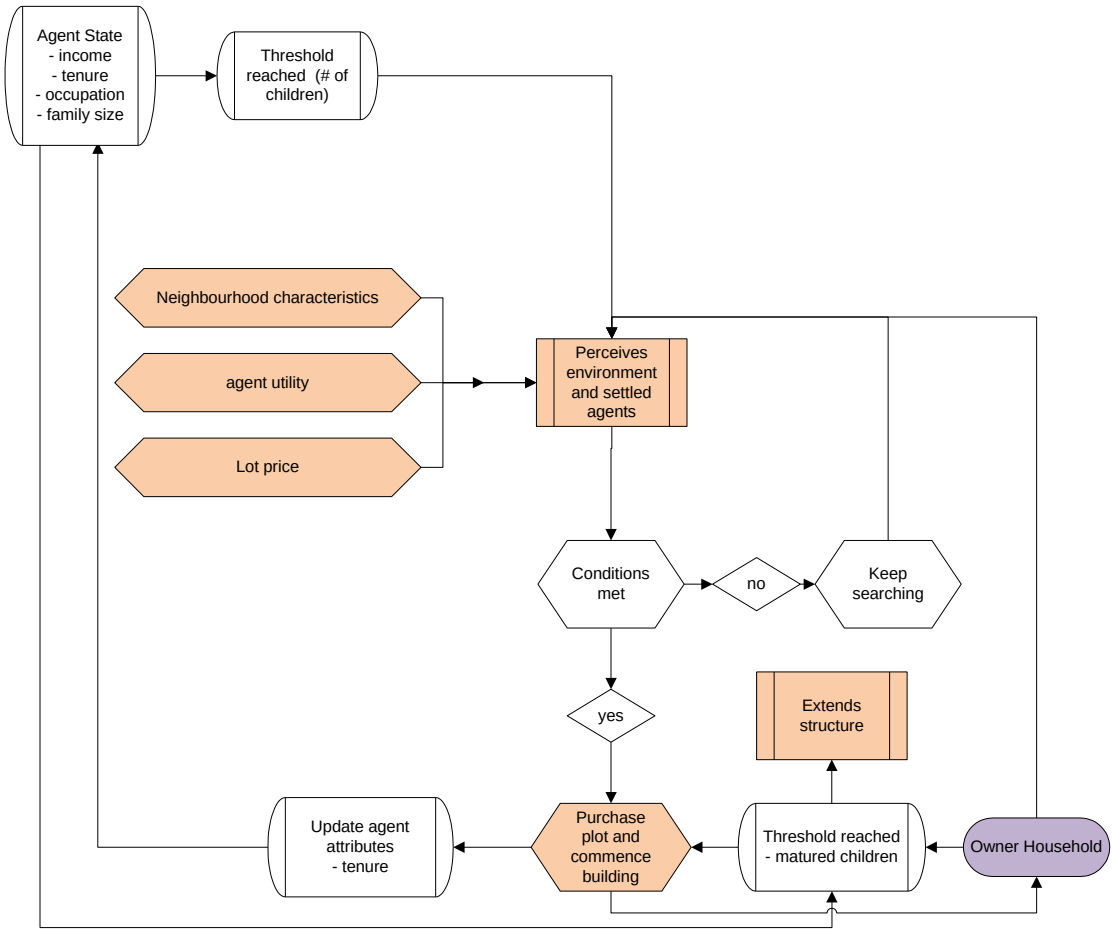

Figure 6-6: Modules combined: micro-level behaviour

6.2.3. Global parameters

The model is fed by global parameters (or experimental factors) such as the rural-urban migration rate, crude birth rate, ratio of tenants to potential owners, ratio of self-employed headed households to formally-employed headed households, income distribution (can be ordinal data), and the inflation rate which affects the rate of construction of houses (Table 6-12). These are all external to the micro-level behavioural modules and can be adjusted by the user. They also enable the model to be run under plausible future scenarios, in which these parameters may change. At every run of the model, the user sets the values for the parameters.

Birth rate: The municipality of Kinondoni (where Hanna Nassif is located) undergoes a 4.1 % annual population increase, as stated in Dar es Salaam City Council (2004), where 2 % is due to natural population increase. This is garnered from the stated 40/1000 women crude birth rate and with 50 % of the population being women (ibid). Thus, each year there is a probability of 2 % (0.02) that a household will have a child.

Rural-urban migration rate: It is assumed the other 2.1 % of the population growth p.a. comes from the rural-urban migrant population.

Tenant / owner ratio: The proportion of tenants to potential owners (or immediate builders) in the migrant population is approximately 90:10 (89:11). This is estimated from data collected in the 2009 survey. Thus, from the migrants, 10 % will seek a plot and start building immediately, while 90 % are absorbed in the available rooms for rent. This absorption of tenants is represented in the model, but the movement of tenants within the settlement is not to be shown explicitly in the computer model. It is assumed the supply of rooms is greater than or equal to the demand in each time step.

Formal / self-employment ratio: In 1998, a survey of 256 individuals by the University College of Land and Architectural Studies (UCLAS) in Dar es Salaam revealed that the proportion of households headed by paid wage earners to households headed by self-employed individuals in Hanna Nassif in 1998 was 42 % to 58 % (Sheuya, 2004). Therefore in each 1 year time step, of the immediate builders 42 % are paid wage earners and 58 % are self-employed.

Inflation: From the macro-level analysis conducted in the study, it was found that every increase in inflation rate of 1 % results in a reduction in the volume of construction by approximately 2.5 %[9]. This will be incorporated into the model. The manner in which this affects the model will be via the volume of housing construction that takes place at every time step by controlling the number of ticks allowed. This process can be addressed during the calibration step of the model implementation.

Income distribution: The ratio of low/medium/high income earners used is 14:8:3 (56:32:12). The derivation of this distribution has been discussed in Section 6.2.1.

Parameter	Description
Birth rate	determines the probability that a household will have a child at each time step
Rural-urban migration rate	determines the quantity of residents entering the settlement at each time step as a percentage of the existing population
Ratio of potential owners to tenants	of the total number of residents entering the settlement, the ratio of immediate builders to tenants
Ratio of self-employed to formally employed agents	ratio for the entire population
Income distribution	sets the initial state of the agents in the agent transformation module

Table 6-12: Global parameters

[9] Note that this is an estimation and may not be used in absolute terms

6.2.4. Macro level

The macro-level of the model represents and results from the collective growth of the informal settlement, which is fed by individual actions of the agents involved. The growth in this context is comparable to the notion of emergence which, in complexity theory, is the manner in which simple interactions give rise to complex systems and patterns. The ability to adjust the global parameters which feed the system allows for experimentation via the model.

Environment

The environment is spatially explicit, having the geographical locations of infrastructure, services, and biophysical constraints within. Figures 6-7 through 6-9 show the preferential factors and associated agent welfare at each location. A Nearest Facility network analysis based on walk time (seconds) was conducted in ArcGIS to identify the nearest local market to the settlement (Figure 6-8) and bus stop (Figure 6-9). Biophysical constraints such as flood prone areas and steep slopes, as well as the relative agent utility (disutility) values associated with each, are found in Figures 6-10 and 6-11 below. Given the irregular layout of road and footpath infrastructure, and thus the building polygons, the model is designed within a vector environment. Although raster may have computational advantages, it will not adequately represent the spatial layout of the settlement.

Each polygon represents occupied or undeveloped building polygons, all following the building footprint of the 1992 building data layer available. It is suggested here that the polygons are modelled as immobile agents, each having the following dynamic attributes:

- Agent utility values (Figures 6-12 and 6-13)
- Estimated lot price (Figure 6-14)
- Agent income range
- Agent occupation type
- Availability

The relative lot price was estimated by averaging the utility values for each plot for the different agents along with the relative welfare associated with presence of proper drainage (Figure 6-15). The utility values are based on agent location preferences and biophysical constraints. Since the agent has to make a location decision based on utility, lot price, and socioeconomic background of neighbours, these three elements are kept separate. These three conditions need to be met, following an if-then command in the decision-making module, before the agent chooses a location.

The function used to determine agent utility is the following:

$$U_{r(x,y)} = \sum_{i=1}^{m}(1-\gamma) + \sum_{i=1}^{n}(1+\ \delta)$$

Equation 6-1: Agent utility function

In Equation 6-1 where the utility U for each agent r is determined, m represents the number of factors and n represents the number of constraints considered for location i; γ represents the standardized distance value from each factor, while δ represents the standardized distance from each constraint. There are 2 factors and 2 constraints considered for each agent. Distance values are calculated using the Near function in ArcGIS then the values are standardized around the maximum. Weights applied to each factor and constraint is assumed to be the same due to the lack of adequate quantitative data to determine factor weights. For the formally-employed agents, the main factors considered were the bus stop and secondary roads, while for the self-employed agents the main factors were roads and nearest local market. The location of water taps was intended for inclusion in the utility function; however, spatial data on location of these was not available and had to be disregarded momentarily. Both factors and constraints contribute to agent utility associated with each location (see Figures 6-12 and 6-13). Equation 6-1 was found to be adequate for calculating agent utility as it captures the advantages of close proximity to preferential factors and distance away from constraints.

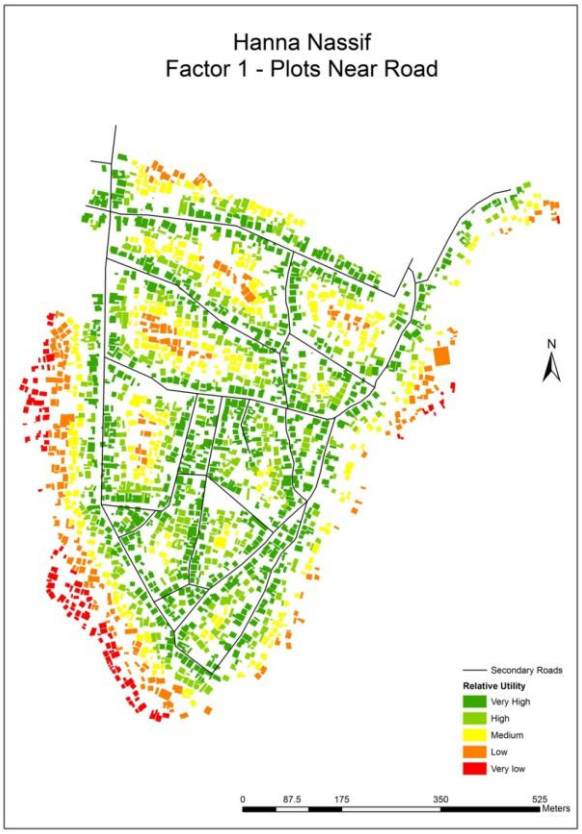

Figure 6-7: Factor 1: Secondary roads and associated agent welfare

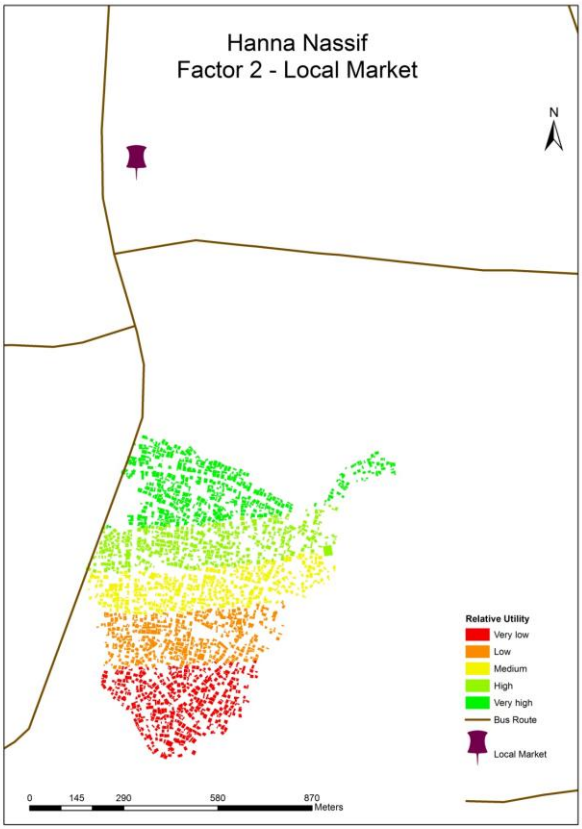

Figure 6-8: Factor 2: Nearest local market and associated agent welfare

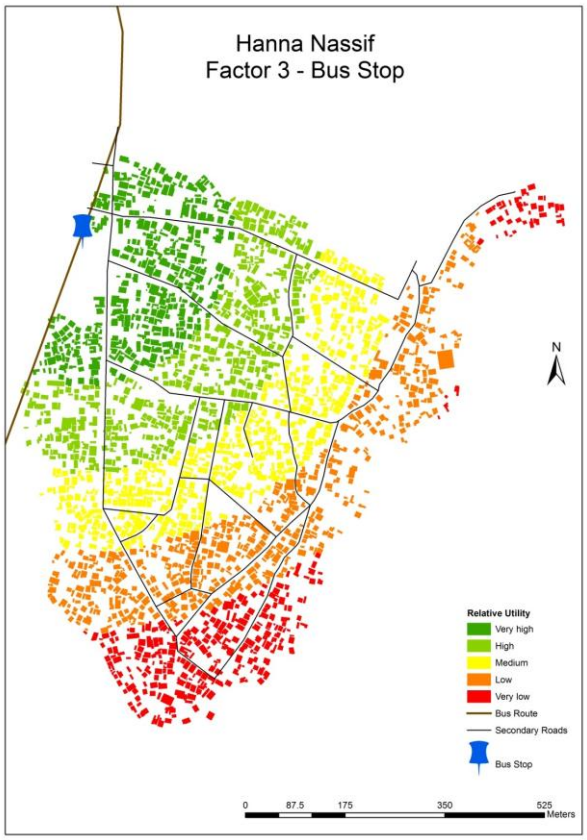

Figure 6-9: Factor 3: Nearest bus stop and associated agent welfare

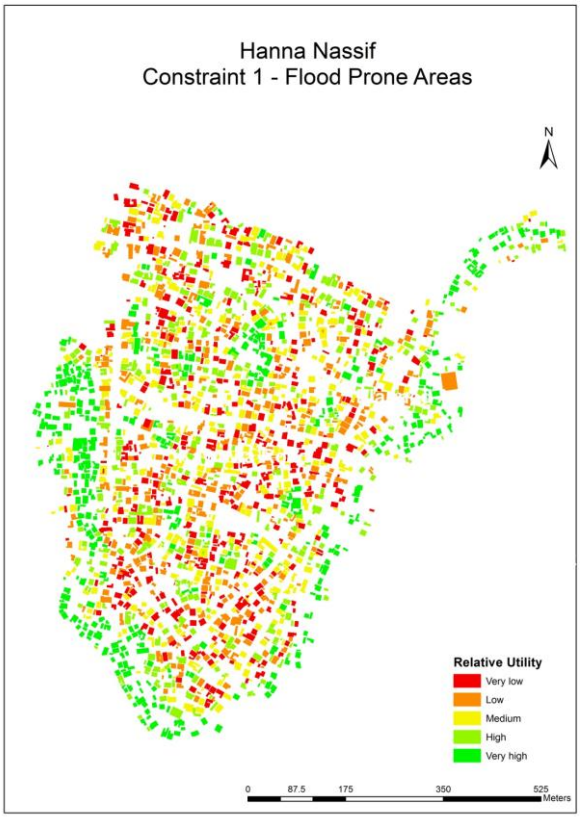

Figure 6-10: Constraint 1: Flood-Prone areas and associated welfare (disutility)

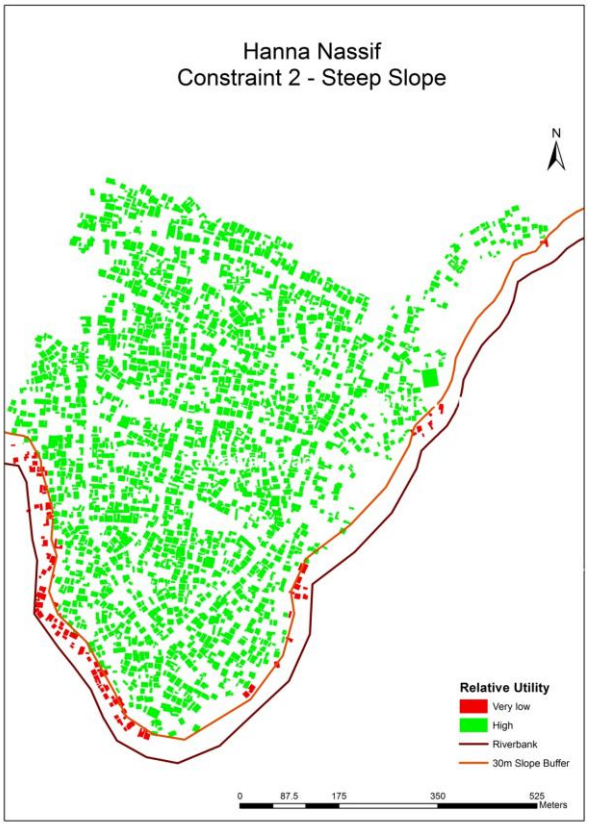

Figure 6-11: Constraint 2: Steep slopes and associated welfare (disutility)

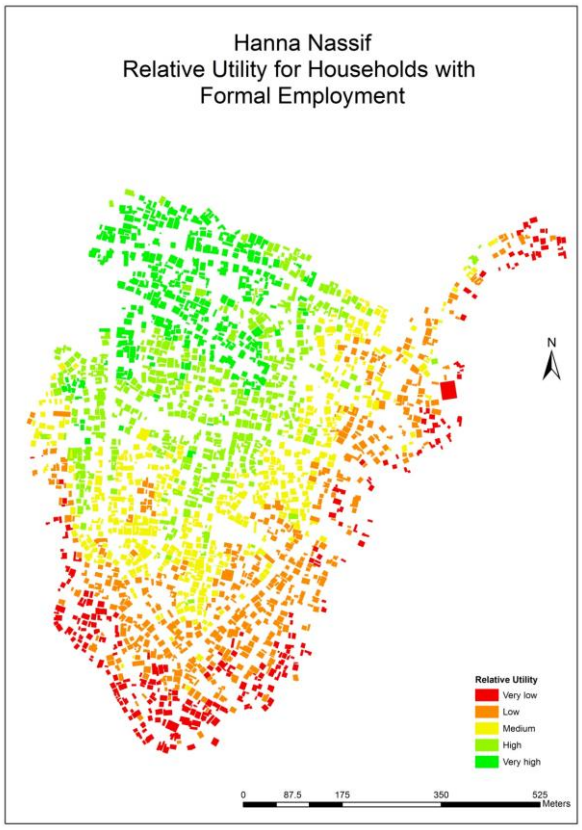

Figure 6-12: Relative agent utility: agents with formal employment

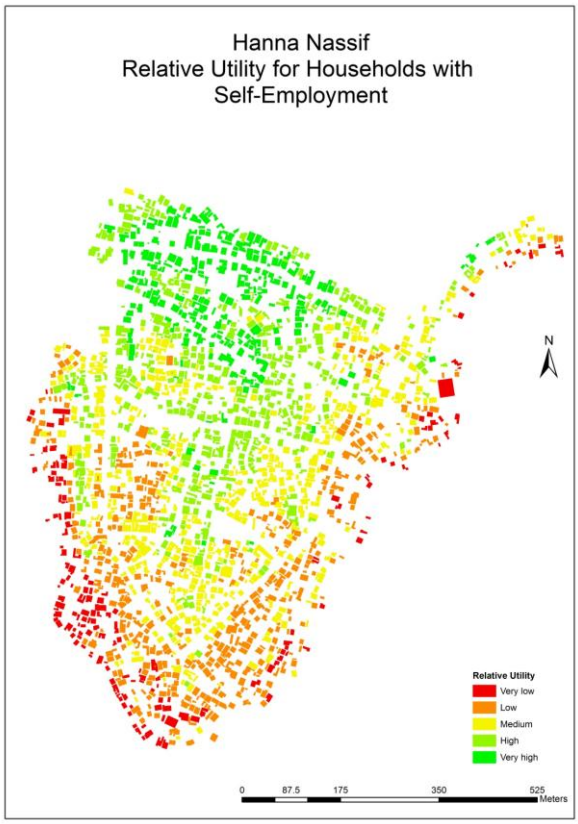

Figure 6-13: Relative agent utility: agents with self-employment

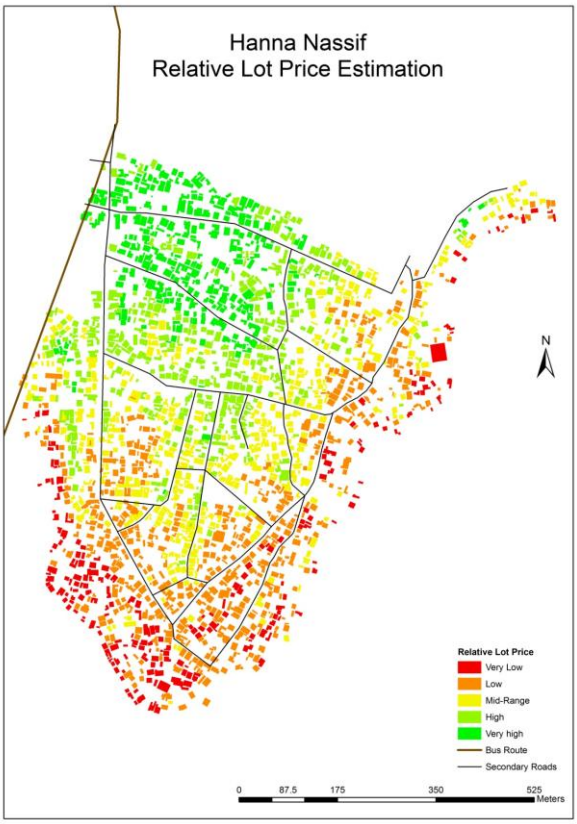

Figure 6-14: Relative lot price estimation

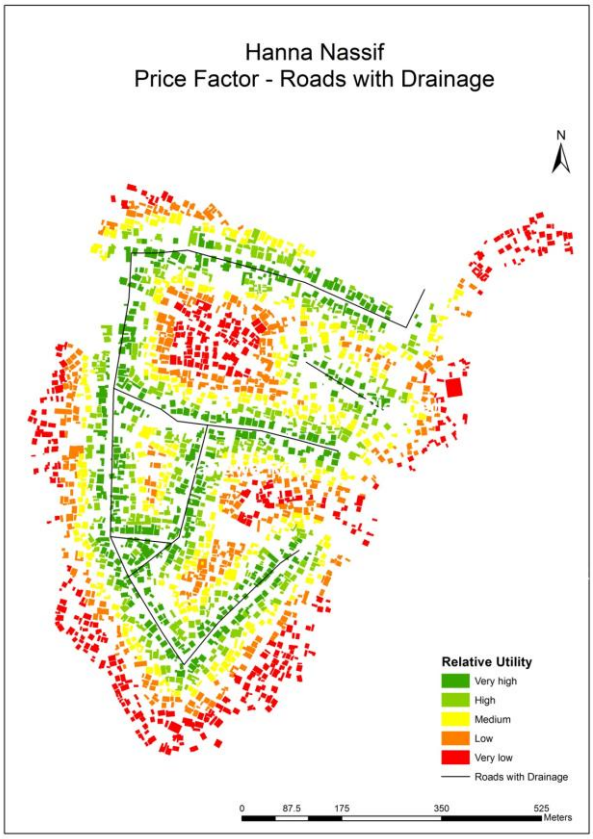

Figure 6-15: Plots with proper drainage

6.2.5. Time

Each time step of the model will simulate 1 year of settlement development. The time span of one year was chosen because of the rapid growth that takes place within the settlement (by way of simultaneous construction). Less than 1 year would not be adequate due to the fact that households typically take at least 1 year to complete a housing structure. This information was obtained from the household survey conducted.

6.2.6. Model assumptions

The following assumptions are made throughout the development of this conceptual model:

- The population growth p.a. for Hanna Nassif is assumed to be same as the municipality in which it lies, Kinondoni;
- With a crude birth rate of 40/1000 female (or 2 % of the population), it is assumed that 2.1 % of the population growth p.a. arises from the rural-urban migrant population;
- It is assumed that the tenant population entering the settlement (90 % of population) is absorbed in the available rooms for rent;
- For each agent, the weights associated with preferential location factors are assumed to be the same;
- A distance of 20 m (66 feet) away from riverbank was considered to be too steep for occupation and was used as a buffer when calculating agent utility;
- It is assumed that starter households consist of one adult female and one adult male; there are variations to this composition that are expected to balance off, thereby rendering this the norm;
- 18 is assumed to be the normal age of maturation, after which the need for additional space is experienced by each household; and
- The relative estimated lot price is assumed based on the average of the utility value for each location for all types of agents and the presence of proper drainage.

6.2.7. Data limitations

Below is a list of data requirements found necessary for model implementation but that are unavailable at this time. This shortcoming is compensated for by making the assumptions listed in Section 6.2.6.

- Geographical location of water kiosks
- Socioeconomic characteristics of already settled agents
- Quantitative data on preferential factor and constraints weighting
- Size of starter households
- Children's age of departure from owner households

6.2.8. Requirements for model implementation

The model can be implemented for the settlement of Hanna Nassif using the concept described in this report, presuming the assumptions are adequate. An attempt is made to provide sufficient information on current and past trends for all global parameters as well as the stochastic specifications for the two micro-level modules. However, the computer model will require verification, calibration, and its own form of validation. Thus, it is necessary to have retrospective spatial data on settlement growth, with preferably equal temporal intervals, say 5 or 10 years. Remotely sensed high resolution images can be utilized to derive building polygon layers for use in a GIS environment.

Additionally, the data on water points within the settlement is required. Time restrictions prevented the acquisition of such data for the purposes of this study. However, this spatial data should be easily accessible from Ardhi University in Dar es Salaam or other sources.

For exploration in a wider geographic context, an attempt is made to provide specifications for implementation of a computer model. These are presented in the concluding section of this report (Section 8.0).

6.2.9. Recommended software package

The suggested software package to be used is Repast Symphony (RepastS) as this provides for working in a spatially explicit vector environment. Furthermore, RepastS has been developed almost exclusively for social science simulation and possesses many advantages over other agent based modelling frameworks (Section 2.3.1).

6.3. Validation results

This section describes the manner in which the model concept was validated by subject matter experts (SMEs). An SME is an individual who is believed to possess better-than-normal expertise or insight into a particular discipline, system, or process due to his or her position, education, training, or experience and has been chosen "to participate in the …validation…" of a model (Defense Modeling and Simulation Office, 2006). Two experts in the field of agent based modelling and 1 in the area of informal settlement growth in developing country cities (including Dar es Salaam) reviewed the model concept (Annex 3). First, the main suggestions and comments are presented, followed by the criteria for incorporation into the model concept.

SMEs in the area of ABM were provided with the model concept description similar to what can be found in Section 6.2 of this document. The concept then, however, was structured in a manner that rendered it more difficult to interpret and understand. Figure 6-16 gives an overview of the model in its original form, to which explanatory text was added and submitted as the model concept overview in December 2009/January 2010. Figure 6-17 shows an example of the agent behaviour for a tenant agent with formal employment as presented in the original overview.

SMEs with knowledge and experience in the area of informal settlement growth in Dar es Salaam were provided with the same concept overview described above. However, they were also provided with additional information on the background information that was used to derive the model concept. This additional information can be found in Section 6.1.

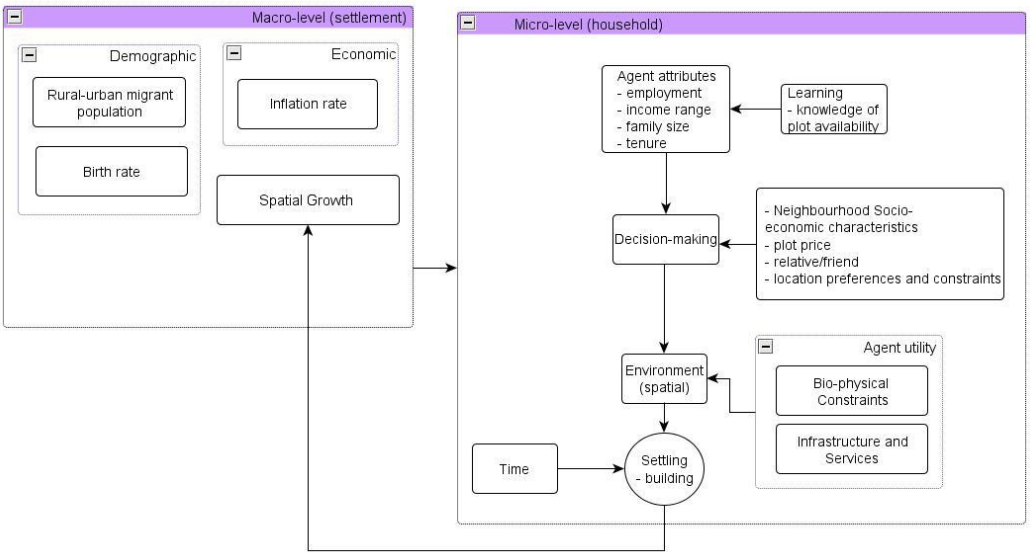

Figure 6-16: Original model overview

6.3.1. Criteria for incorporation of recommendations

Feedback comments and recommendations from the SMEs were evaluated for adoption based on 4 criteria:

1. Ease of implementation
   - Data availability
   - Time necessary for implementation

   Recommendations were incorporated into the model concept if the required spatial, qualitative or quantitative data was immediately available. Also, there it was necessary to have enough time to implement the suggestions. For example, recommendations made toward restructuring the model concept were more quickly implemented than those pertaining to the elements of the micro-level modules.

2. Frequency of occurrence

   Comments which occurred more than once and met criteria 1 above were considered for immediate inclusion in the concept. For example, the suggestion on restructuring the agent behavioural rules was made by more than one SME and was thus incorporated immediately. The result of this was the organization of the rules into modules for easier interpretation.

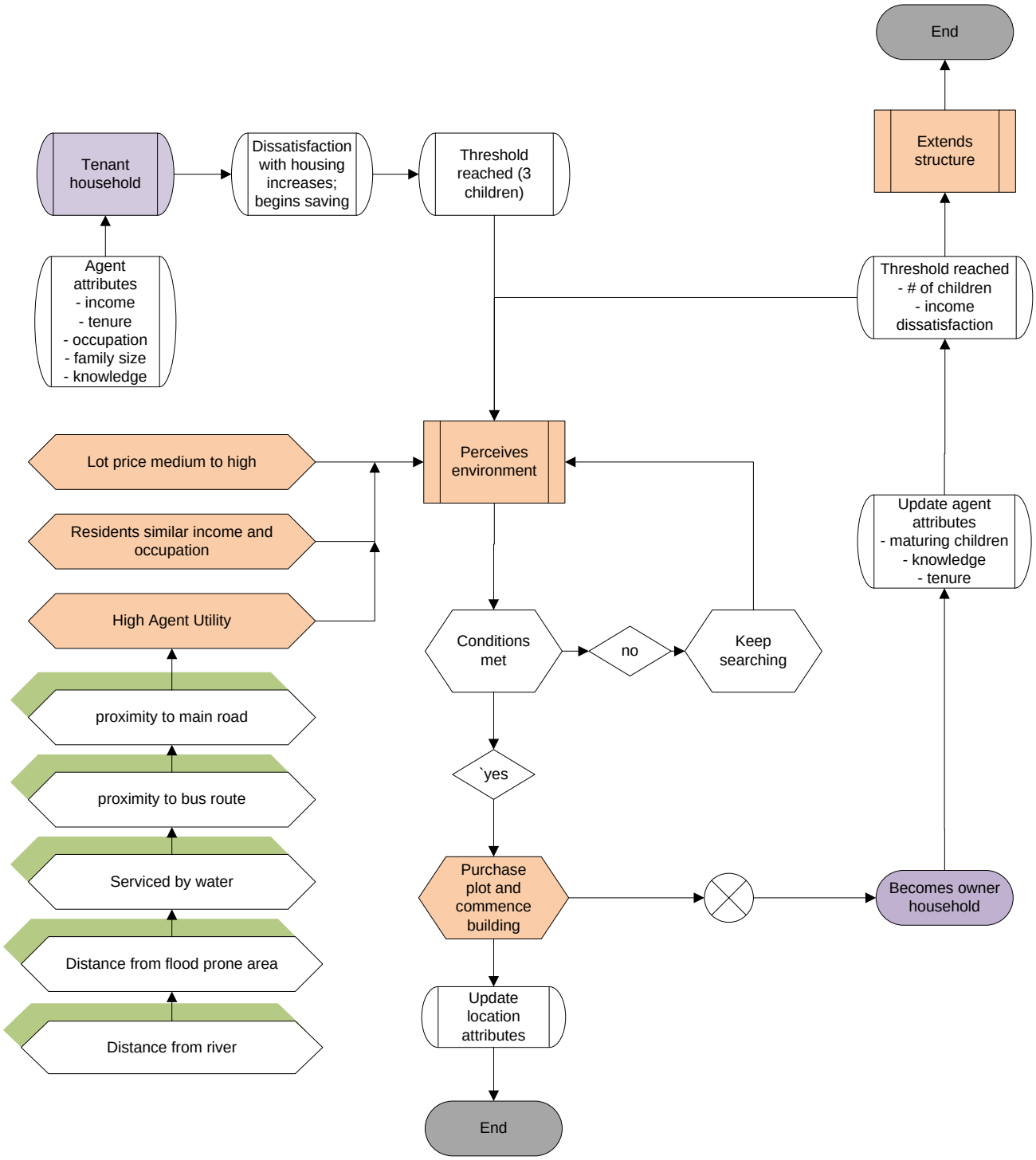

Figure 6-17: Original agent behavioural rules for formally employed tenant agent

3. Similarity or relativity to other recommendations

Some recommendations, while framed or structured differently, are very similar to others made by other SMEs. In some instances, a suggestion made by one SME complements another made by a different SME. For example, the informal settlement SME suggested that the settlement age be considered specifically when including the rural-urban migrant population as supplying the bulk of house owners in the settlement. While it may not have been clear how to include this suggestion, insight was gained from an ABM expert to include the population density as a global parameter. Population density increases with settlement age and thus becomes an unattractive force for the

settlement. However, the precise rate at which this decrease in attraction occurs is not clear and is time- and data- dependent. Thus, it was recommended for future consideration in Section 8.3.

4. No direct conflict with other suggestions or recommendations
   Recommendations that directly oppose those made by other SMEs were not to be considered for inclusion. There are no instances where this was found.

Recommendations which did not satisfy criteria 1 above but met criteria 4 and either criteria 2 or 3 were proposed for incorporation prior to implementation of the computer model. These recommendations can be found in Section 8.3.2.

6.3.2. SME comments and suggestions

Below is a list of comments and suggestions made by the various SMEs. They are separated by field of expertise. A more elaborate description of the main comments received from each SME can be found in Annex 3 of this report. There are additional suggestions made within the model overview submitted to each SME, which for reasons of page volume cannot be presented in their original form. These comments are also listed below in summary.

Agent based modelling

Suggestions incorporated into the model

- Show that the agents form the core of the model.
- Ratios such as rural-urban migrant population, birth rate, and inflation rate, while pertinent to the macro-level, should be treated as global parameters as they immediately affect the micro-level of the model. These will become experimental factors in the model.
- The agent behavioural rules, presented in its original form, should be separated into sub-models for easier implementation. Agent steps should be separate from external drivers.
- There needs to be clarification of what agent 'states' are and the variables which comprise such state. The dynamics of the agent attributes may be represented in a separate sub-model.
- Ensure that the variable household size is represented as "number of children" as described in text and not "family size" as found in the behavioural rules.
- Separate sub-model rules from 'time' section, as it was originally presented.
- It is suggested that plots be modelled as simplified agents that do not change location but possess dynamic attributes. Thus, at the micro-level there would be household agents and plot agents and at the macro-level there would be urban population (representing sum of household agents) and the built environment (sum of plot agents).
- The chosen utility function should be justified.
- Separate (make clear) plot and agent attributes.

Suggestions proposed for future consideration

- Consideration of the factor/constraint weighting as experimental factors.

- The assumption made that a starter house is comprised of two adult individuals is not normally made; this information is usually fed by real statistics.
- Households moving out or dying off should be incorporated, if possible.
- The agent transformation module should incorporate changes in income and employment type over time, if possible.
- Consider adding a fixed number of agents at each time step, rather than using a percentage of the existing population.
- Revision of the conceptual model under a complex system mindset. The informal settlement should be seen as a system with both physical and social elements. There are physical and social elements at both micro-level (plots and households) and at the macro-level (population, income distribution, etc. and infrastructure, extent of the settlement, etc.)[10].

Informal settlement growth

Comments on the model

- The city-wide rural-urban migrant population seems to be the main source of potential owner tenants, while presently housing demand by sitting tenants or owners' children can be assumed to be very high. This is due to the settlement's central location and relative old age. However, it is true that in the early stages most of the house builders/owners are derived from the rural-urban migrant population as presented in the model.
- There is a high correlation among the effects of the variables of roads, drainage, and flooding and bus stop and local market. The model outcome might be the same without some variables. However, they should be kept in the model concept for they may become relevant for application to other areas in the city.
- The effectiveness of the social network as presented originally is questioned. However, it may be attempted if it is possible as it may prove relevant for application to other areas (See Section 8.3).

Suggestions proposed for future consideration

- A short consideration of the local land and housing market would be adequate.

Validation exercise review

Many of the comments received from the ABM experts were structural and presentational as they reflect the model concept in its original form, which is very complicated and the 2 modules are represented as one (See Figure 6-17). The suggestions regarding the separation of agent behavioural rules into separate modules were found to be quite useful. As a result, the presentation of the model in its current form provides for simplification of rules and easier comprehension of the processes of the

[10] An attempt is made to derive the model with a complex system mindset. However, the elements mentioned here are not made explicit in the concept itself.

system and interactions among these processes. The suggestion and attempt made to view the informal settlement as a complex system with positive feedback mechanisms also allowed for a clearer understanding and representation of the system being modelled (settlement), and relationship between the micro components (agents) and the system. Other comments regarded using the right terminology in the text and ensuring that the sub-sections are placed within the right larger sections and headings.

The comments received from the SME in the area of settlement growth regarded the logic of the model and the effectiveness or usefulness of incorporating the variables in the utility function and the social network. During the implementation of the computer model there may be recognition that the incorporation of factors identified are rendered ineffective. However, as discussed previously this may be the case for Hanna Nassif only because of the spatial layout and presence of one exit to the primary road network. If the concept is applied elsewhere these factors may prove effective. There were also comments made on the background information for the model (section that precedes model concept in this report). These also regarded using proper terminology and on the proper description of the household survey from which much of the concept information was garnered.

6.3.3. The proposed social network

The original version of the model concept (prior to validation) proposed the implementation of a social network within which the household agents would be able to find an available plot to locate themselves. This concept was later further developed through a learning module whereby existing owner agents would be able to acquire knowledge of plot availability over time. The design of the social network was later removed from the model concept for two reasons:

1. Its effectiveness was questioned for Hanna Nassif (though suggestion was made for its incorporation if possible simply to view its effect on the simulation outcome), and
2. It is not certain as to whether the social network, as presented in its original form (See Annex 5), can be modelled within the RepastS ABM software framework.

RepastS has the capacity to model neural and social networks using its NetworkBuilder where networks are built under the principle of agents as nodes and the relationship between them as edges. It is uncertain, however, whether RepastS has the capacity to model dynamic networks. The nature of the relationship can be specified (e.g. kinship, business). The social network, as it is presented in Annex 5 requires the modelling of a dynamic network which has the capacity to grow and change over time as new owner agents are added to the model or tenure status of a tenant agent changes. It was not ascertained from literature whether this is possible in RepastS.

7. Reflection on methodological approach

This chapter provides a critical review of the methodological approach used in answering the research questions set for the study. There are areas in the methodology that are deemed open for improvement; these are discussed briefly.

7.1. Macro-level analysis of development activity

The direction taken in analyzing the macroeconomic policy and macroeconomic variable implications on housing construction activity is somewhat narrow, thus rendering the deductions made hasty. While there may exist a relationship between inflation rates or REER and development activity at the household level, these may not be the only variables that can explain the decrease or increase in activity. There are perhaps other macro-level factors that contribute to this phenomenon. A better approach would have been to consider other factors and variables and conduct a multiple regression analysis to identify the explanatory variable(s) for the observed rate of development.

Another concern with the approach in this area is the use of a small sample size for the supply of construction volume. Preferably, quantitative data should be used. This may be garnered from spatial data, i.e. quantifying volume of housing structures from remotely sensed images or GIS data layers derived from the same.

Furthermore, the time periods under which the development activity was analyzed are large, making precise inferences difficult. For this reason, the effects of the macroeconomic variables are said to be estimates only. The exact effect of each unit change is to be determined in the calibration phase of model implementation.

7.2. Conducting field work by remote means and its implications

The manner in which the household questionnaire survey was conducted was also somewhat challenging. Although the survey is perceived successful, despite lack of presence from ITC in the field, there were a number of administrative issues faced relating to its commencement and completion.

The main issues of concern encountered with attempting to conduct the field work from a distance related to the limited experience in carrying out a survey in this particular area. The students were tasked with the added responsibilities of submitting the letter of request to the Kinondoni Municipal Council for permission to conduct the survey and also of retrieving the letter from the Chief Town Planner. Also, the reconnaissance survey took longer than expected and was considered additional days in the field. Furthermore, the questionnaires were expected to be scanned and emailed to The

Netherlands on a daily basis; however, the students encountered various problems with scanner and internet access. Communication with this author, communication with each other, and transportation to and from the study area were all additional costs not initially budgeted for. There were also other smaller problems regarding having to cover unexpected costs.

Perhaps the main matter of concern was the delay in commencing the survey due to having to acquire permission from the municipal council and other factors as well. There was not enough support from staff members of Ardhi University in overseeing the execution of the survey, as was short-sightedly anticipated. Thus, the lack of experience with the particular location resulted in reliance on students for breakdown of costs, time, and other matters which could not be substantiated in such short timeframe.

Furthermore, the tardiness in commencing the survey had a ripple effect on the progression of the research itself. Having received the data completely until mid-November resulted in a somewhat rushed development of the model concept in order to have provided adequate time for the validation exercise by the SMEs. Also, not being able to visit the study area prevented the author from gaining firsthand experience of the phenomenon and also disallowed the acquisition of particular spatial data, for example the location of the water kiosks.

7.3. Computer programming

During the development of the model concept, there were issues faced with trying to determine what the capacity and requirements for the suggested software package is. Structuring of the concept and proper formulation of stochastic elements to meet the requirements of modelling in RepastS was also challenging. A conceptual model, such as the one developed here, should be developed in tandem with the individual responsible for implementing the model. It is not expected that the computer programmer will be on board at the early stages of the research initiative; however, she should become involved in the project at the time the model concept itself is being drafted.
As in many other research projects, time was an issue here as well. A project such as this, in the absence of a computer programmer on board, requires that the researcher has some knowledge of programming in order to address the issues discussed previously. Time restrictions did not allow for this.

7.4. Concept overview document

Another minor issue encountered during the research was trying to decide what to include in the conceptual model overview that was submitted to the SMEs. Each individual SME as his or her own preference for the extent of detail in the document. Also, the author tried to balance the provision of detail with minimizing page volume due to the fact that the validation exercise was conducted Pro bono and experts had no contractual obligations with the researcher.

8. Conclusion and further recommendations

The development of the concept for an agent based model is perceived to be the first and most crucial step toward building and running the computer based model. Although envisaged as a concept that pertains to modelling spatial growth within the settlement of Hanna Nassif itself, this study has derived an initial understanding of the socioeconomic aspects of growth of informal settlements throughout the city of Dar es Salaam. It is necessary, however, to initially implement a computer model focused only on Hanna Nassif. Through the initial computer model, the ensuing procedural steps of verification, calibration, and validation (of the computer-based model) can take place.

8.1. Objectives revisited – a summary of findings

1. **To analyze micro-level agent decision-making behaviour in residential location and economic processes which result in housing construction activity**;

Micro-level behaviour pertaining to housing construction was analyzed mainly using data attained from a household questionnaire survey. The main elements covered under this research objective were the socioeconomic triggers of housing construction, household budget constraint, factors that contribute to location decision-making, biophysical constraints which negatively affect location choices, and the preferred socioeconomic structure of neighbourhoods.

The main trigger of housing construction was found to be the accommodation of children and other relatives. Approximately 70 % of respondents cited this as the reason for building the house they currently reside in.

The budget constraint describes the set of options of 'goods' that is available to the household. This was determined in order to ascertain the portion of household income that is geared toward housing provision. The particular research question was intended for direct incorporation into the model concept, while the ambitions were to approach the research problem from a purely economic standpoint. It was later determined that the economic aspect alone does not adequately capture the households' push toward construction. Nonetheless, the information garnered from answering this question is useful for understanding the economic activities for those households who do intend to construct new housing structures. Almost 74 % of respondents cited savings from income as the source of funding for housing. From the income, a certain percentage was spent on monthly expenditures. From the surplus a portion is spent on irregular items such as extra food, entertainment, etc. and the remainder is saved for housing. While the range of values was large (0-100 %), the median and mean percentages saved for housing were both 70 %. The budget constraint for a household intent in construction can be represented as:

Savings for housing construction = (*monthly income – household expenditure*) x (*0.7*)

More than 60 % of respondents claimed to use the saved money for either supplementing new rooms to current structures or building new houses.

The main factors that attract households to particular locations were found to be proximity to water points, roads, footpaths, local market, and bus route, with priorities for water points, roads, and footpaths. These elements cover preferential factors for all households, not any agent in particular. Constraints avoided in location decision-making were flood prone areas, steep slopes, and swamps. The main characteristic of neighbours that house owners found attractive was similar income, and to a lesser extent similar type of occupation, i.e. residents prefer to reside in locations where neighbours were from a similar socioeconomic group.

2. **To determine the effects of macro-economic conditions and policies which have the potential of influencing agent behaviour in the housing process**; and

This objective was met by answering three research questions which included identifying and discussing macroeconomic policy implementation, analyzing macroeconomic variables such as inflation rate and real effective exchange rate during policy implementation, and determining the effect of these on construction activity.

Three main policy episodes were identified from literature. Nineteen seventy to 1978 marked the first half of the social policy and inward reform episode when the state played a major role in the economy. The inflation rates averaged around 11 % and the real effective exchange rate was about 105% of the 2000 forex rate. From the responses gathered in the household survey, around 26% of new rooms were built during this period. The second half of this period ran from 1979-1985. During this time the inflation rate rose to an average of just over 28% and the real effective exchange rate rose to 154% of the 2000 rate. Construction of new rooms during this time only comprised around 14% of the total from the responses.

The second policy episode ran from 1986-1993. Policies implemented during this time targeted efficiency and economic growth. Two main economic recovery programs were implemented. However, this era was marked by maintained high inflation rates which averaged about 30% annually. The real effective exchange rate was not as high as other periods: 92% relative to the 2000 exchange rate. The effective of high inflation was sustained low construction activity; only about 20% of new rooms were constructed during this time. The programs implemented during this time, however, had a positive impact on the macro-economic conditions, which became evident in the following era.

The third episode ran from 1994-2004. This episode sought to combine the strategies attempted in previous periods and initiatives attempted during this time were therefore termed “initiatives to

combine growth and social policy". These initiatives coupled with those in the latter stages of the efficiency and growth episode were effective in reducing the average inflation rate. During this time the inflation rate was only approximately 8%, while the real effective exchange rate was kept at 90% relative to the 2000 exchange rate. This phase of reduced inflation rates saw an increase in construction of housing structures. From the responses obtained, over 40% of new rooms were built during this period.

3. **To develop and validate a conceptual model of residential decision-making behaviour of household agents based on the micro- and macro-level driving forces affecting behavioural patterns**.

The information provided in research objectives 1 and 2 provided a broad overview of household behaviour pertaining to housing development, as well as a general idea of the impact of macro-economic conditions on micro-level activity. A statistical test was conducted to identify the household attribute most practical for categorization of household agents; this was found to be nature of employment. Additionally, more than 65 % of the owner households were found to arise from former tenant households. Thus, agents were categorized both by nature of employment (self- and formal employment) and land tenure status (tenants and owners). In addition to the information provided in previous research questions 1 and 2, it was determined necessary to answer these questions as they related to each type of agent. Therefore, local preferences and economic elements were determined for each type of agent, specifically differentiating between self-employed and formally employed household agents. This analysis was carried to identify particular decision-making behaviour of agents for the purpose of the model concept.

The model concept derived from the above information was validated by SMEs in the field of agent based modelling and informal settlement growth in Dar es Salaam. The original concept comprised of agent behavioural rules and its demographic and economic exogenous influences, particularly inflation rate. Feedback from experts revealed the need to restructure the model concept to reflect the dynamics of micro-level and macro-level activities of the system and the feedback loops between them. Also, the demographic and economic forces specified in the original concept, along with additional ones, were recommended for incorporation as global parameters for the model. These parameters would provide for experimentation with the model. Recommendations made by experts were assessed for incorporation based on 4 main criteria. Those which did not fit 1 or more criteria were suggested for future consideration.

8.2. Research adjustments

In the incipient stages of this study, the aim was to approach the agent based model from a purely economic perspective, specifically the micro-level component of the model. The budget constraint at the micro-level was determined because the original intention was to estimate at any given time what the household financial potential would be for the purposes of construction. That is, how much cash a

household would have at hand that is geared toward housing construction. It was perceived then that when the household agent reaches a financial threshold they would commence construction. During the course of data analysis, however, it was realized that the main drivers of housing construction are those derived from the social transformations that take place at the household level, i.e. the increase in household size. Thus, the micro-level component of the model was adjusted to reflect this household dynamic attribute as the main trigger of construction. While the findings described in Sections 4.0 and 6.1 of this document may represent the real scenario for a household whose intentions are to begin construction, it may only be so when the "psychological stress" as described by Seek (1983) has been reached. Thus, it is more pragmatic to model this household level change as the trigger to the decision-making module as detailed in Section 6.2.

8.3. Future considerations for the model

The model concept has not considered the mortality rate of the population. This variable has not been incorporated into the model mainly due to conflicting data observed from international organization websites (e.g. 34/1000; 12/1000; 32/1000). Mortality rate can be incorporated by specifying its stochastic effects on the model. For example, if the rate is 3.4 %, then there is a 0.034 probability that a household member will die off at each time step. Furthermore, the concept of houses being destroyed as a result of disasters, whether natural or anthropogenic, has not been incorporated into the model. The rationale behind its exclusion is the lack of data on the rate at which this occurs. Additionally, because the spatial scope of this study is one settlement with only one exit toward the primary road network leading to the CBD, the CBD itself was not modelled as a factor in calculating utility. This element was found to be very important by over 90 % of the respondents in the questionnaire survey. Thus, for consideration of expansion, the CBD must be considered an attractive factor for agent utility calculation. Also, collectively, household agents identified the presence of footpaths as an attractive factor to location choice. This may be considered providing the spatial data exists for this.

8.3.1. Data requirements

Further than making an attempt at visualizing the growth phenomenon in a rather simplistic manner, the study provides a window for the identification of spatial and qualitative data and software requirements for a model that can potentially go beyond the settlement of Hanna Nassif. Additionally, it is possible that more agents may be identified when the spatial coverage of the model expands. Quantitative data requirements would include, among others to be identified:

- Income distribution
- Owner : tenant ratio in rural-urban migrant population
- Sources of employment
- Rural-urban migration rate (trends known)
- Birth rate (trends known)
- Factor and constraint weighting by agents

Spatial data requirements include:

- Biophysical factors such as topography, river system, hazardous areas, swamps, etc.
- Infrastructure and services

These are in addition to all the requirements made in Section 6.2.8, now being applicable to a different geographical area. Additionally, the social network proposed in Section 8.3 should be attempted as it may prove significant in the model outcome.

8.3.2. Expert suggestions not yet incorporated

The following are considerations for future implementation of the model that resulted from expert suggestions during the validation exercise.

- An attempt should be made to start building the model in Repast. Starting from the tutorial models should provide further insights on how to structure the actual model and provide guidance on how the implement problem at hand.
- Some insight into the local land and housing market should be considered.
- It is agreed that in the early stages of settlement development the majority of house owners are derived from the rural-urban migrant population. However, as the settlement ages the demand for housing arises from descendants of existing house owners. This aspect is necessary for consideration so as to accurately capture the growth phenomenon.
- The population density was recommended for incorporation as a global parameter. This aspect may account for the decrease in attractiveness of older settlements to the rural-urban migrant population. It may be observed that as the settlement ages and population density increases, migrants seek other settlements or areas to reside. There would need to be a spatial analysis of development trends over time to determine the relationship between settlement age or population density and degree of desirability of the particular settlement.

8.3.3. Model relevance and use

The computer model that may result from this concept should be able to model land-use change in Hanna Nassif. The provision of global parameters allows any user to visualize physical and spatial results of modelling under current demographic and economic trends, as well as under probable changes that may result from government or other form of intervention. Different outcomes can be explored in this manner. In this context, the model serves mainly as a visualization and experimentation tool.

Providing that implementation is successful for Hanna Nassif, however, provides optimism for modelling within a larger spatial context. Although the geographical context and the physical composition of the environment, socioeconomic and demographic characteristics may differ from the case of Hanna Nassif, the concept provides a general overview of how growth takes place and can be adapted to apply to a much larger setting within the city of Dar es Salaam. According to Macal & North, (2006), it is typical for successful projects to begin small using one or more of the desktop

agent based modelling and simulation (ABMS) tools and then grow into the larger-scale ABMS toolkits in stages.

Modelling in this larger environment may identify the need to incorporate other agents. For example, in Hanna Nassif the role of the state has been mainly in upgrading of infrastructure and service facilities; however, the need may arise to model the state as an agent implementing planning schemes where possible in the city (supposing that a model may be implemented at the city level).

This larger-scale computer model has the potential to serve as a spatial planning support tool. Given the data requirements described in Section 8.3.1, the model can become a useful tool in predicting spatial growth in the city under varying future scenarios. Experimentation can be achieved through the exploration of simulation outcomes by adjusting the global parameters of the model. This feature may allow decision-makers to test the effects of either potential policies targeted at rural or urban residents or potential planning instruments within the urban environment. For example the effects on spatial growth of poverty reduction strategies can be tested. For this to be accomplished, the income distribution parameter would be adjusted when running the simulation.

The model should also provide for the visualization of the effects of developing or improving infrastructure or public service elements in the settlement or settlements being modelled. For example, it should be able to simulate the movement of agents across the landscape and the cumulative impacts on land-use change if roads or water pumps are installed in a certain location. These are two potential changes that can occur in a certain location as a result of government intervention.

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10. Annexes

Annex 1: Household Questionnaire

English Version

*Sample Number*_____
Date: _____
Interviewer: _____
Recorder: _____

Good morning/afternoon sir/madam, my name is _____. I am conducting a short survey with house owners in Hanna Nassif, which looks at the economic aspects of housing construction. The survey is part of a research project being conducted by a student from ITC, an institute in The Netherlands. The questionnaire consists of 25 short questions, which should not take more than 25 minutes to answer. I would be very grateful for your participation in this survey.

I. Personal Details

1. What is the source of your employment?

   Government□ Private□ Self-employed□ Not employed□

2. What level of education did you obtain or are in the process of obtaining?

   Primary school Diploma□ Secondary school Diploma□ College Degree□ Bachelor's Degree□ Master's Degree□ PhD□ Other _____

3. On average, how much money does your entire household earn per month (in TShs)?

   Less than 30,000□ 31,000-50,000□ 51,000-70,000□ 71,000-90,000□ more than 90,000□

4. On average, how much money does your household spend on food, water, electricity, school, and other items every month (in TShs)?

   Less than 30,000□ 31,000-50,000□ 51,000-70,000□ 71,000-90,000□ more than 90,000□

5. Were you a tenant somewhere else before you built this house? _____

6. Were you living in this settlement or another one in Dar es Salaam? _____ If yes, which one (write name of area)? _____

7. Why did you decide to construct the house you currently live in?

   Accommodate children and relatives□ build rooms to rent□ provide own working space□ provide a Madrassa□ better access to employment□

   Other _____

8. How many family members do you have in your household?

   No. of children _____ No. of adults (over 18) ____ No. of adults employed ____

II. House/Plot Details

9. How many rooms do you have in your house in total?

   Bedrooms ____ Kitchen ____ Bathroom/toilet ____ Storage ____ Shop ____

   Living room ____ Office ____ Other _____

10. How many tenants do you have in the building? _____ persons

11. How much did you pay for the plot of land on which the house is built?

    Less than 130,000□ 130,000-260,000□ 261,000-390,000□ 391,000-520,000□ More than 520,000□

12. What year did you purchase this plot? _____

13. How many buildings did you construct during the following years?

	Buildings	**Bedrooms**	**Duration**	**Source of Finance**
1967-1977	_____	_____	_____	_____
1978-1985	_____	_____	_____	_____
1986-1993	_____	_____	_____	_____
1994-2004	_____	_____	_____	_____

14. How much would it cost for you to construct a three bedroom house with a toilet, living room, kitchen and veranda today? _____

III. Location choice/development process

15. Please indicate the importance of each of the factors listed below when you where choosing a plot of land to build on. E.g. How important was it to be near to the CBD? How important was it to be near to an industrial area? Etc.

Feature	**Very important**	**Important**	**Somewhat important**	**Not important**
CBD	□	□	□	□
Industrial area	□	□	□	□
Local market	□	□	□	□
Planned area	□	□	□	□
Main road	□	□	□	□
Footpath	□	□	□	□
School	□	□	□	□
Clinic/dispensary	□	□	□	□
Bus route	□	□	□	□
Water pump	□	□	□	□
Mosque/church	□	□	□	□
Family/friends	□	□	□	□

Tribesmen	□	□	□	□
Other _____	□	□	□	□
Other _____	□	□	□	□

16. Please indicate the importance of **avoiding** each of the factors listed below when you where choosing a plot of land to build on. E.g. How important was it to **avoid** swamps? How important was it to **avoid** hilly areas? Etc.

Feature	**Very important to avoid**	**Important to avoid**	**Somewhat important to avoid**	**Not important**
High slope	□	□	□	□
Flood area	□	□	□	□
Swamp	□	□	□	□
Riverbank	□	□	□	□
Noisy bars	□	□	□	□
Factories	□	□	□	□
Other _____	□	□	□	□
Other _____	□	□	□	□

17. When you were looking for a place to build, what kind of neighbourhood did you look for? People who have:

    same occupation□ same religion□ same tribe□ same education□ same income□ higher income□

    Other _____

18. How did you know that this is a good place to live? _____

19. Was there any person(s) who assisted you in choosing this plot? If yes, who was it (family/friend/local leader/other .....) and how did they assist you? _____

    _____

20. If you were given an extra TShs 500,000 this month, how much would you spend on clothes, food, entertainment, etc. and how much would you save for building construction? Would you contribute to communal services or facilities such as road maintenance, drainage, school, water supply, sewer, street lighting?

    Spend on clothes, food, entertainment, etc. _____ Save for other building _____

    Contribution to communal facilities _____

21. The money saved for building construction would be spent on which of the following?

    Improvement of building□ Extension of Building□ A new building□

22. If you would construct another building, where would you construct it?

    on this plot□ another plot in this settlement□ another settlement□

23. What would be the reason for constructing another building?

Accommodate children and relatives□ build rooms to rent□ provide own working space□ provide a Madrassa□ better access to employment□
Other _____

24. Were you able to get the location you wanted when you bought this plot?

_____

25. If no, what is it about the location that you do not like?

_____

Household Questionnaire

Swahili Version

Nambari ya sampuli _____
Tarehe: _____
Mhoji: _____
Muandikishaji: _____

Hujambo, Jina langu ni _____. Nina fanya muhtasari na wenye nyumba katika Hanna Nassif, kuhusu vipengele za uchumi katika ujenzi wa makao. Muhtasari huu ni sehemu ya utafiti amabo unatekelezwa na mwanafunzi kutoka ITC, ambayo ni chuo katika Nchi ya Uholanzi. Fomu hii ina maswali 25 zinazo hitaji muda wa dakika 25 kujibu. Nita shukuru sana kama ungeweza kushiriki katika muhtasari huu.

IV. Vipengele Vya Kibinafsi

1. Unapata ajira kwa jinsi gani ?

   Serikali□ Sekta ya Binafsi□ mwenyewe □ Huna ajira□

2. Umefikisha kiwango kipi cha masomo au ni kiwango kipi ungali unatafuta kufika?

   Shule ya msingi □ Shule ya upili □ College Degree□ Chuo Kikuu□ Degree ya Master □ PhD□ Ingine _____

3. Kwa wastani, ni kiwango kipi cha pesa ambayo nyummba hii inapatas kwa mwezi(TShs)

   Chini ya 30,000□ 31,000-50,000□ 51,000-70,000□ 71,000-90,000□ Zaidi ya 90,000□

4. Kwa wastani, nyumba hii inatumia pesa kiwango kipi kwa chakula, maji, sitima, shule, na kadhalika kwa mwezi (TShs)

   Chini ya 30,000□ 31,000-50,000□ 51,000-70,000□ 71,000-90,000□ zaidi ya 90,000□

5. Ulikuwa ume komboa nyumba kwingine kabla ya kujenga nyumba hii? _____

6. Ulikuwa unasihi katika kijiji hiki au kingine huku Dar es Salaam? _____kama ndio, andika jina hio kijiji_____

7. Ni kwasababu gani uliamua kujenga nyumba unayo ishi sasa?

   Kwasabu ya watoto na familia □ kujenga nyumba za kukodesha□ Kutengeneza pahali pa kufanyia kazi□ pahali pa Madrassa□ kwasababu ya kukaribia mahali pa ajira□ ingine_____

8. Je,kuna watu wangapi katika familia hii?

   Idadi ya watoto _____ Idadi ya waliokomaa (miaka 18 kuenda juu) ____ idadi ya waliokomaa na wame ajiriwa ____

V. Vipengele vya Nyumba / Ramu

9. Kuna vyumba ngapi katika nyumba hii?

   Vyumba vya kulala ____ Jikoni ____ Choo/bafu ____ Ghala ____ Duka_____ Ofisi_____

   Sebule _____

10. Kuna wapangaji wangapi kwa hii nyumba ? watu_____

11. Ulilipa pesa ngapi kumiliki ardhi ambayo nyumba hii imejengwa?

    Chini ya 130,000□ 130,000-260,000□ 261,000-390,000□ 391,000-520,000□ Zaidi ya 520,000□

12. Ulinunua hii ardhi mwaka gani?_____

13. Katika muda wa miaka zilizo kwa hii orodha, umejenga nyumba ngapi?

kwa ujenzi	**Nyumba**	**Vyumba vya kulala**	**Muda**	**Asili za hela zilizotumika**
1967-1977	_____	_____	_____	_____
1978-1985	_____	_____	_____	_____
1986-1993	_____	_____	_____	_____
1994-2004	_____	_____	_____	_____

14. Ingekugharimu pesa ngapi kujenga nyumba ya vyumba tatu, choo, sebule, jikoni na veranda leo?

VI. Chaguo la lokeshen /Harakati za maendeleo

15. Kutoka orodha ilioko hapa chini, tafadhali onyesha umuhimu wa vipengele ulipokuwa ukichagua ardhi/kiwanja cha kujenga nyumba. Kama vile kuwa karibu na CBD kuna umuhimu gani?

Vipengele	**Muhumu zaidi Muhimu**	**Muhimu**	**Muhimu Kidogo**	**Sio**
CBD	□	□	□	□
Sehemu ya Viwanda	□	□	□	□
Soko	□	□	□	□
Sehemu iliopangwa	□	□	□	□
Barabara Kuu	□	□	□	□
kichochoro	□	□	□	□
Shule	□	□	□	□
Zahanati	□	□	□	□
Kituo cha Basi	□	□	□	□
Bomba la Maji	□	□	□	□
Msikiti/Kanisa	□	□	□	□
Familia/marafiki	□	□	□	□
Kabila/Utani	□	□	□	□
Ingine _____	□	□	□	□

16. Tafadhali onyesha umuhimu wa kujiepusha na vipengele ambavyo vime orodheshwa hap chini ulipokuwa na chagua ardhi/kiwanja cha kujenga nyumba. Kama vile, Kuna umuhimu gani wa kujenga mbali na sehemu ya bwawa au matope?

Vipengele	**Muhimu zaidi kuepuka Kuepuka**	**Muhimu**	**Muhimu kidogo**	**Sio Muhimu**
Mteremko wa Juu	□	□	□	□
Sehemu ya mafuriko	□	□	□	□
Bwawa/Matope	□	□	□	□
Kando la mto	□	□	□	□
Baa zinazo makelele	□	□	□	□
Karakana/ banda	□	□	□	□
Ingine _____	□	□	□	□

17. Ulipokuwa ukitafuta mahali pa kujenga, ni mtaa wa aina gani ulitafuta? Watu waliokuwa na : kazi inayofanana na yako□ dhini kama yako□ kabila kama yako□ elimu kama yako□ mapato kama yako□ mapato zaidi ya mapato yako□ Ingine _____

18. Ulijuaje kwamba hapa ni pahali pazuri pakuishi? _____

19. Kuna watu wowote ambao walikusaidia katika kuchagua ardhi/shamba hii? Kama ndio, tafadhali wataje (familia, rafiki, kiongozi au wengine)..... na walikusaidia kwa njia gani?_____

20. Kama ungepewa kwa ziada TShs 500,000 mwezi huu, ungetumia kiwango kipi kwa nguo, chakula, burudani na kadhalika na ni kiwango kipi ungeweka kwa akiba ya kujenga nyumba? Na pia ungekuwa tayari kuchangia katika kuleta huduma za jumuiya kama vile barabara, shule, stima, maj, michirizi?

    Tumia kwa nguo, chakula, burudani na kadhalika _____ Weka kwa akiba ya kujenga_____ Tumia katika huduma za jumuiya_____

21. Pesa katika akiba ya kujenga ingetumiwa kwa ?

    Kwa kuboresha nyumba□ Kueneza/kuongeza Nyumba□ kujenga nyumba mpya□

22. Kama ungejenga nyumba mpya, ungeijenga wapi?

    Katika hii ardhi□ katika ardhi nyingine ndani ya hii mtaa□ Mtaa ingine□

23. Ni sababu gani ingefanya ujenge nyumba ingine?

    Kwasababu ya watoto na jamaa□ nyumba za kukodesha□ pahali pa kufanyia kazi binafsi□ pahali pa Madrassa□ kukaribia pahali pa ajira□ ingine_____

24. Uliweza kupata pahali ulipotaka uliponunua ardhi hii? _____

25. Kama la, ni nini haupendi kuhusu pahali hapa?_____

Annex 2: SME Questions for validation exercise

Agent based modelling

1. Representation enumeration:

1.1 Are all elements and aspects of the item to be represented included? These include entities, states, behaviours, actions, tasks, etc.

1.2 Which ones were omitted?

1.3 Are those omitted pertinent for intended simulation applications?

2. Assessment of assumptions pertaining to conceptual model

2.1 Are all assumptions identified?

2.2 Are implications of these assumptions clearly and correctly identified?

2.3 What assumptions were omitted and what implications need clarification?

3. Conclusion and synopsis of the review findings, clearly separating fact from interpretation, and explaining the significance of the findings

4. Recommendations for improving simulation correctness or credibility or future conceptual model validation review processes

Informal settlement growth

1. Representation enumeration:

1.1 Are all elements and aspects of the item to be represented included? These include entities, behaviours, actions, and tasks.

1.2 Which ones were omitted?

1.3 Are those omitted pertinent for intended simulation applications?

2. Assessment of assumptions pertaining to conceptual model

2.1 Are all assumptions identified?

2.2 Are implications of these assumptions clearly and correctly identified?

2.3 What assumptions were omitted and what implications need clarification?

3. Conclusion and synopsis of the review findings, separating fact from interpretation, and explaining the significance of the findings

4. Recommendations for improving credibility or future conceptual model validation review processes

Annex 3: Area of expertise, list of publications, and comments from Subject Matter Experts

(1) Mr. Friedrich Krebs

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SESAM Research Group
Center for Environmental Systems Research
Kurt-Wolters-Str. 3
Kassel, Germany
Email: krebs@usf.uni-kassel.de
Phone: +49 561 804 3931 / 6215

Area of expertise: Agent based modelling, mathematics, computer science, artificial life

Experience:
1988 - 1995 Study of Mathematics, Environmental Systems Analysis, and Computer Science, Diploma Degree in Mathematics, with focus on Environmental Systems Analysis.
1990 - 1997 Employed as assistant / free lancer in Systems Analysis, Modelling and Simulation at the Center for Environmental Systems Research, Kassel, Germany.
1998 - 1999 Employed as scientific assistant at ICLARM (Manila, Philippines) in the project Development of Sustainability Indicators for Integrated Agriculture-Aquaculture Farming Systems.
Since 1998 Free lance consultant in Systems Analysis and Design, Management Information Systems, Database Development. Projects in Germany, Malaysia, Hungary, and Philippines.
Since 2005 Researcher at the Center for Environmental Systems Research, Kassel, Germany.

List of Publications

Krebs, F.; Bossel, H. (1997)

Emergent value orientation in self-organization of an animat

Ecological Modelling, 96, 143-164

Holzhauer, S.; Krebs, F.; Ernst, A. (2009)

A Regional, Spatially Explicit Agent-Based Model of Individual Acceptance of Climate Change Adaptation Measures

Accepted Paper: 6th European Social Simulation Association Conference, Guildford, UK.

Krebs, F.; Ernst, A. (2008.09)

Comparing the impact of different compensation policies on collective land reclamation.

Proceedings of the 5th European Social Simulation Association Conference, Brescia, Italy.

Krebs, F.; Elbers, M. & Ernst, A. (2008)

Modelling the social and economic dimensions of farmer decision making under conditions of water stress.

Proceedings of the 1st ICC workshop on complexity in social systems, Lissabon.

Krebs, F. ; Elbers, M. & Ernst, A. (2007)

Modelling social and economic influences on the decision making of farmers in the Odra region.

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In S. Takahashi, D. Sallach & J. Rouchier (eds.), Advancing Social Simulation: The First World Congress (pp. 319-330). Berlin: Springer.

Simon, K.-H.; Krebs, F. (2002)
Die Rolle von Modellierungsansätzen bei der Erklärung, beim Verständnis und bei der Initiierung sozial-ökologischer Transformationen
In: Balzer, I.; Wächter, M. (Hrsg.) Sozial-ökologische Forschung - Ergebnisse der Sondierungsprojekte aus dem BMBF-Förderschwerpunkt. ökom-Verlag, München, Deutschland, 389-407

Krebs, F.; Holzhauer, S.; Ernst, A. (2009)
Modelling the role of neighbourhood support in regional climate change adaptation
Annual Conference of the Royal Geographic Society, Manchester, UK.

Holzhauer, S.; Krebs, F.; Ernst, A. (2009)
A Regional, Spatially Explicit Agent-Based Model of Individual Acceptance of Climate Change Adaptation Measures
6th European Social Simulation Association Conference, Guildford, UK.

Krebs, F.; Ernst, A. (2008.09)
Comparing the impact of different compensation policies on collective land reclamation.
5th European Social Simulation Association Conference, Brescia, Italy.

Krebs, F.; Ernst, A. (2008.08)
Modeling the impact of different social and policy conditions on collective land reclamation.
Annual Conference of the Royal Geographic Society, London, UK.

Krebs, F.; Elbers, M. & Ernst, A. (2008.01)
Modelling the social and economic dimensions of farmer decision making under conditions of water stress.
1st ICC Workshop on Complexity in Social Systems, Lissabon.

Krebs, F.; Elbers, M. & Ernst, A. (2007.09)
Modelling social and economic influences on the decision making of farmers in the Odra region.
4th European Social Simulation Conference ESSA 2007, Toulouse.

Ernst, A. ; Krebs, F. & Zehnpfund, C. (2006.08)
Dynamics of task oriented agent behavior in multiple layer social networks.
1st World Congress on Social Simulation, Kyoto, Japan.

Krebs, F. (1997.04)
System and environmental orientors in evolution of artificial life
Second German Workshop on Artificial Life (1GWAL97) University of Dortmund, Haus Bommerholz, Dortmund, Germany

Ernst, A.; Bernedo Schneider, G. Elbers, M. Holzhauer, S. Klemm, D. Krebs, F. Kuhn, S. Seidl, R. (2009.01)

Socio-Environmental Systems Analysis and Modelling - SESAM.

Workshop on Rich Cognitive Models for Policy Design and Simulation, Leiden, The Netherlands.

Elbers, M.; Ernst, A.; Krebs, F.; Holzhauer, S.; Klemm, D. (2009)

LARA: A Lightweight Architecture for boundedly Rational citizen Agents

6th European Social Simulation Association Conference, Guildford, UK.

From: Friedrich Krebs [mailto:krebs@usf.uni-kassel.de]
Sent: Thursday, January 21, 2010 3:45 PM
To: Gina Young
Cc: Johannes Flacke
Subject: Re: {Filename?} Concpetual model review

dear gina,
thanks for the concept paper.
you present a quite detailed outline for a simulation model with a rich empirical grounding for the simulations to be conducted (displayed e.g. in the factor and constraint maps and the behavioural rules for the agents). i feel that the behaviour rules of the agents as shown in figures 11 and 12 are also well elaborated and suitable for an agent-based simulation model.
first, some comments on your wording concerning agent-based modelling (abm): abm modellers usually talk about the process of building a model (that is what you are doing now) as "modelling". in the process of modelling you identify "agent types", which in your case are 4 different agent types. therefore, in the last paragraph on page 2 you would rather say "Based on these findings, four main agent types were identified...".
the process of "simulation" comes in when the model has been built and you let it run. simulations start with an initialisation phase during which (among other things) an initial population of agents is constructed, e.g. in terms of numbers of simulated agents of each type.
i find the sequence of simulation steps that you present in section 1.2.5 a bit problematic. for an abm you need to distinguish between steps that occur on the level of agents and steps that are external drivers.
the following might serve as an example: i assume that an agent represents one household. for each household agent you have (among other attributes) the number of children living in that household and their respective age (maturing). in each simulation year and for each of the agents you would increase the number of children by one with a probability of 0.02 (birthrate) and increase the age of all existing children by 1. with the thresholds shown in figs 11 and 12 this eventually triggers household agents search for new building plots. this process happens for all modelled households independently in every year (agent level behaviour) an external driver is population growth through migration. this process would be modelled by adding new agents to the simulation. you would assign suitable attributes to each of them (e.g. a certain number of children in a certain age) and than have them look for locations to build their houses. from your data i understand that 2.1 % of the existing population is to be added as new household agents (probably adding a fixed number each year is more realistic).
for your work as a next step i would advice you to start setting up a model in repast. try to start-out from the tutorial models - this will give you some insights in how agent-based models are structered and some guidance on how to implement your specific case.
i hope my comments help,
best wishes, friedrich.

(2) Ms. Flavia Feitosa

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Area of expertise: multi-agent models, spatially-explicit ABMs, urban planning

Experience:

2006-present	Center for Development Research, Bonn, Germany **Junior Researcher**
2005 - 2006	National Institute for Space Research, São José dos Campos, Brazil **Research Assistant** Research Project „Spatial Measures for Representing Socio-Territorial Inequalities“
2004	Institute of Statistics and Information Management, New University of Lisbon, Portugal **Research Traineeship** Research Project „Geo-Self-Organizing Mapping (GEO-SOM)“
2001-2002	Geography Institute, Martin Luther University, Halle (Saale), Germany **Research Traineeship**, DAAD Assistance to GIS projects
2000-2001	Department of Architecture and Urban Planning, Federal University of Santa Catarina, Florianóp **Undergraduate Research Assistant**, Scientific Initiation Program, CNPq Research Project „Natural and Built Landscape: The Case of Lagoa da Conceição, Brazil“
1999-2000	T&C Associados – Landscape Architecture and Urban Projects, Florianópolis, Brazil **Practical Traineeship**
1998-1999	Department of Architecture and Urban Planning, Federal University of Santa Catarina, Florianóp **Undergraduate Research Assistant**, Special Training Program, PET/CAPES Extension Project „Technical Consultancy: Movement Pro-quality of Life in Pântano do Sul, Flori

List of Publications:

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MANUSCRIPTS IN PROGRESS

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Feitosa, F. F., Le, Quang Bao, Vlek, Paul L. G. (in preparation) Residential Choice, Segregation, and Neighborhood Types in São José dos Campos, Brazil: A Nested Logit Approach. Urban Studies.

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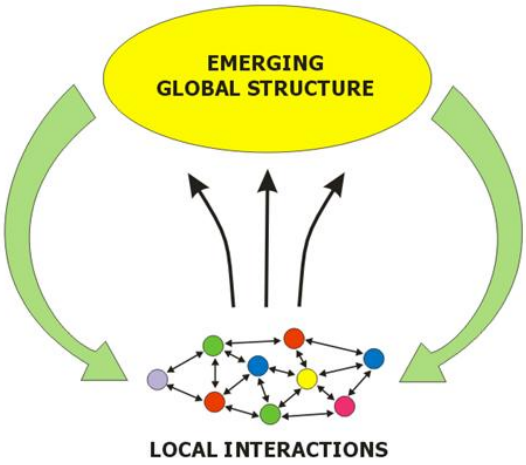
First Comments

The elements included in the conceptual model seen appropriated for a good representation of land-use dynamics that lead to the spatial extension of a settlement.

My main suggestion here is conceptual and focuses on the classification of these elements as components of micro- or macro-levels of the system to be represented. I understand that the study seeks to represent an urban system (an informal settlement), which has a dynamic global structure (macro-level) that emerges from household interactions/decisions that occur at the micro-level. The picture below illustrates this principle of emergence, which is a hallmark of complexity:



Considering this complex system mindset, the **macro-level of the system** would consider the overall structure of the informal settlement, instead of demographic and economic elements. This overall structure includes not only physical/environmental characteristics (e.g.: extent of the settlement, infrastructure…), but also the characteristics of the population (e.g., total number of inhabitants, population density, average income and income distribution).

The demographic and economic elements that are currently presented in the conceptual model as "macro-level" (rural-urban migration, birth rate, and inflation rate) could be included as **external factors**.

At the **micro-level**, there are the households, with their state, decision-making mechanisms/rules, and probably other mechanisms that regard internal household dynamics (size, tenure, knowledge (!), etc.). The conceptual model shows these elements, but I would suggest differentiating them a bit better (entity, state, rules…).

It is also important to have a framework that shows the feedback between micro and macro levels. The macro structure emerges from the household interactions/decisions at the micro-level, but the behaviour of the household is also affected by the macro structure. For instance, as the settlement

grows, its characteristics (price, infrastructure, etc) also changes and such modifications influence the behaviour of households (macro-level feedback to the micro- level).

In the conceptual framework, there are elements like "neighbourhood socioeconomic characteristics" and "plot price", which could be seen as examples of this type of feedback.

Review Report

Review personnel

Information used Documents: model overview, review report
(Interactions with developer/developing team)

Date January 20, 2009

Validation Tasks and Questions

5. Representation enumeration:

5.1 Are all elements and aspects of the item to be represented included? These include entities, states, behaviours, actions, tasks, etc.

The elements included in the conceptual model seen appropriated for a good representation of land-use dynamics that lead to the spatial extension of a settlement. Indeed, the model includes interesting variables. It is the case of inflation rate, a macroeconomic variable that, despite its importance, is seldom considered in urban growth models.

Minors:

-At the micro-level, the entity "agent" and its state could be represented explicitly, instead of included in the agent transformation module. It is a way to separate this entity or agent, from algorithms or sub-models (representing rules/interactions).

-The global parameters are only linked to the micro-level, when in fact they affect the whole system.

-The "target-system" should be stated more clearly (more details in answer 4).

-The agent state includes the variable "family size" (and not "number of children"), while the threshold to activate the decision-making module uses the variable "number of children".

5.2 Which ones were omitted?

The inclusion of additional elements would depend of the level of detail expected from the model and the peculiarities of the study area. The relevance of elements that could be included cannot be assessed without proper field work and data analysis.

5.3 Are those omitted pertinent for intended simulation applications?
(See answer 1.2)

6. Assessment of assumptions pertaining to conceptual model

6.1 Are all assumptions identified?
Probably not, but it is possible to observe that, for a conceptual model, they are very detailed. The fact that many rules are already described in detail and contain empirical values for their parameters (e.g., section 1.3.1) is also very positive.

6.2 Are implications of these assumptions clearly and correctly identified?
Not possible to answer

6.3 What assumptions were omitted and what implications need clarification?
Not possible to answer

7. Conclusion and synopsis of the review findings, clearly separating fact from interpretation, and explaining the significance of the findings
The work presented is very detailed and complete. It goes beyond the minimal requirements expected from a conceptual model and already presents a set of theoretical specifications and empirical parameters. I do believe that the work provides enough elements to start building a first operational model, using an agent-based platform (e.g., NetLogo).
Nevertheless, one of the main criticisms to the work is still conceptual, and regards the classification of the model elements as components of micro- and macro-levels of a target-system to be represented.

8. Recommendations for improving simulation correctness or credibility or future conceptual model validation review processes

Although some attempts have been already done in this direction, I would recommend to review the conceptual model under a complex system mindset.
First, it is important to define and characterize the target system that is being represented and investigated. Here, the informal settlement is the target system, and can be seen as a type of urban system. It has two types of elements: social and physical. The informal settlement, as a system, is not only its physical form, but also the people who live there.
In Figure 1, these social and physical elements are still a bit confused: the micro-level focuses on social elements (the household) and the macro-level on physical elements (the "physical" growth of the settlement).
In fact, these two types of elements have micro and macro dimensions. At the micro-level, we have the household (social) and the plot or building (physical), and both can be modelled as

agents, although the second is much simpler than the first (it does not perform any action). Each micro element has a state:
-Household: income, family size, etc.
-Plot: size, location, distant from bus stop, etc.

At the macro-level we have the population (social) and the "structure of the settlement" (physical). They also have a state:
-Population: total number of inhabitants, population density, average income and income distribution, etc.
-Physical structure of the settlement: **extent of the settlement**, infrastructure, etc.

The model output that seems to be the focus of this study is the **extent of the physical structure of the settlement** (growth), which will be measured after each simulation cycle. The land-use change that leads to the spatial extension of the settlement (growth) is an emergent property of this complex urban system.

(3) Prof. Dr. Volker Kreibich

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Area of expertise: physical geography; urban development planning; informal urban development and land management in Dar es Salaam

List of Publications

- Urbanisation. Peasants and 'Yuppies' – Unconnected. Vortrag auf der KAAD-Konferenz "Worlds Apart: Local and Global Villages. From Villagisation to Globalisation in One Generation" in Nairobi, 24.–27.7.2003
- Bringing the State back into Urban Growth Regulation – The Tanzanian Experience. Vortrag auf dem N-AERUS Workshop "Beyond the Neo-Liberal Consensus on Urban Development: Other Voices from Europe and the South" am 15.5.2003 in Paris
- Indikatorgebiete für die kleinräumige Wohnungsmarktbeobachtung in Dortmund – ein Werkstattbericht. Überarbeitete Fassung eines Vortrags vor dem Initiativkreis Kommunale Wohnungsmarktbeobachtung NRW in Düsseldorf am 8. 4. 2003 und vor dem Bundesarbeitskreis Wohnungsmarktbeobachtung in Hannover am 15. 5. 2003
- Integrierte Raumplanung und nachhaltige Stadtentwicklung. Vortrag auf dem 10. ZUFO Umweltsymposium in Münster am 27. 11. 2000
- Anforderungen an einen Masterplan Wohnen. Vortrag beim Workshop "Masterplan Wohnen" der Stadt Dortmund am 23. 11. 2000
- Unübersichtliche Märkte brauchen zutreffende Beobachtungsinstrumente. Vortrag auf dem Seminar "Die Wohnungsmarktbeobachtung" des vhw in Köln am 29. 8. 2000
- Die Unübersichtlichkeit des Wohnungsmakrtes, die Wohnungspolitik und der Bedarf an Informationen. Vortrag auf dem Seminar "Kommunale Wohnungsmarktbeobachtung" des difu in Berlin am 4. 9. 2000
- Städte der Zukunft - die Modellstadt Münster. Vortrag am Lehrstuhl "Planungstheorie und Stadtplanung" der RWTH Aachen am 7. 6. 2000
- Harte und weiche Indikatoren zur Beobachtung regionaler Wohnungsmärkte. Vortrag auf der Tagung "Wohnungsmarktbeobachtung der Länder" der Investitionsbank Schleswig-Holstein in Kiel am 23. 6. 2000
- Die Umsetzung des Leitbildes nachhaltiger Siedlungsentwicklung im ExWoSt-Forschungsfeld "Städte der Zukunft". Vortrag im Forschungskolloquium des IÖR Dresden am 17. 5. 2000
- Die räumliche Form der 'europäischen Stadt' im Übergang zum 21. Jahrhundert Vortrag auf dem internationalen Symposium "Die europäische Stadt - ein auslaufendes Modell?" des IRS in Erkner bei Berlin, 16. - 17. 3. 2000

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- Land Management for Urbanisation under Poverty. Vortrag auf der Konferenz "The Relationship between Land Ownership and Land Use in Emerging Land Markets in East Africa" in Nairobi am 25. 2. 2000
- Hauff, Thomas & Kreibich, Volker: Pilot- und Modellprojekte im Handlungsfeld 'Sozialverantwortliche Wohnungsversorgung' der Modellstadt Münster. Vortrag auf der Forschungswerkstatt des ExWoSt-Forschungfeldes "Städte der Zukunft" in Heidelberg, 13. - 14. 1. 2000
- Zum Verhältnis von nachhaltiger und sozial verantwortlicher Wohnungsversorgung. Vortrag auf der Forschungswerkstatt des ExWoSt-Forschungfeldes "Städte der Zukunft" in Heidelberg, 13. - 14. 1. 2000
- Die Erfassung der Motive der Randwanderung. Vortrag auf der Tagung "Wohnungsmarktbeobachtung der Länder" des IÖR Dresden am 12. 11. 1999
- Kombe, Wilbard J.& Kreibich, Volker: Informal Land Management in the South - an Introduction. Vortrag auf der Konferenz "The Interaction between Formal and Informal Land Management in Africa" in Dar es Salaam am 25. 11. 1999
- Vom Nutzen der kompakten Stadt. Vortrag auf dem Workshop "Urbane Modernisierung" des IRPUD am 10. 6. 1999
- Kombe, Wilbard J.& Kreibich, Volker: Land Management as a Response to Public Planning Deficits. Vortrag auf der Tagung der Forschungsgruppe N-AERUS in Venedig am 29. 1. 1999
- Regionale Wohnsiedlungspolitik in der Stadtregion Münster. Vortrag auf der Tagung "Wohnungsmarktbeobachtung der Länder" der Investitionsbank Niedersachsen in Hannover am 15. 2. 1998
- Operationalisierung einer zukunftsfähigen Stadtentwicklung. Vortrag zur Festveranstaltung "125 Jahre Geographie in Halle" am Institut für Geographie der Martin-Luther-Universität Halle-Wittenberg am 23. 10. 1998
- Restructuring the Dortmund housing market. Vortrag auf der Arbeitstagung LiDo20 der Ruhr-Mersey-Arbeitsgruppe in Dortmund am 2. 7. 1998
- Kombe, Wilbard J.& Kreibich, Volker: Socially regulated land management in Tanzania. Vortrag auf dem Workshop "Bodenrecht und Bodenordnung in mrginalen großstädtischen Siedlungsgebieten von Entwicklungsländern" der gtz in Oberursel am 18. 6. 1998
- Die Bestimmung von Armutsinseln mit Verwaltungsvollzugsdaten: Das Beipsield er Stadt Hannover. Vortrag vor dem Arbeitskreis "Wohnungsmarktforschung" am Institut für Geographie der Universität Leipzig am 23. 4. 1998
- L'applicazione dell'Agenda XXI in Germania: il programma ExWoSt. Vortrag am DPTU der Universität La Sapienza in Rom am 19. 3. 1998

(1) From: Volker Kreibich [volker.kreibich@tu-dortmund.de]
Sent: Saturday, 23 January 2010 10:45 AM
To: Gina Young
Subject: Hanna nassif model

Dear Gina,
I have read your text and added my comments (plus a few minor corrections) in the Word version (see attached pdf). In general I can agree with the overall logic and most assumptions. There is, however, one assumption which I would like to question:

- It is more likely that new demand for housing in Hanna Nassif is generated by locals who are descendents of the original settlers and stay with them until they want to set up they own household, and not so much by migrants. Transferring the citywide ratio of birthrate/migration does not seem plausible for a relatively old settlement in the inner city.
- Another problem is the high intercorrelation between some macro variables, namely flooding/drainage/road network and bus stop/local market. For the final version I should like to propose that you provide sections on your research interest and the corresponding aim of your research; on the theoretical concepts (brief) and the corresponding research questions; on the choice of the method (agent based simulation); on the information required and the methods to collect this information; on the validity of your survey – all before you start presenting the model. I suppose that the model outcome would be almost the same without some variables (because of the high intercorrelation);
- I even have doubts about the effect of the social network. A discussion of these aspects would be appropriate; also of the effects of settlement size, because the relatively small size and compactness of Hanna Nassif and the fact that there is only one exit will most likely exert some special effects.
- Finally, a short consideration of the local land and housing market would seem adequate.

I wish you further on good success and would be very much interested in
being informed about your progress.
Yours,
V. Kreibich.

PS: I will try to send you the Word document for easier corrections.

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(2) **AW: Hanna nassif model Volker Kreibich [volker.kreibich@tu-dortmund.de]**
You replied on 25/01/2010 06:18 PM.
Sent: Monday, 25 January 2010 05:24 PM
To: Gina Young

Dear Gina,
thanks a lot for your interesting questions and remarks to which I have tried to reply (see my comments inserted below)…. [DELETED TEXT].

Von: Gina Young [mailto:young22246@itc.nl]
Gesendet: Sonntag, 24. Januar 2010 13:45
An: Volker Kreibich
Betreff: RE: Hanna nassif model

Hello Professor,

Thank you for having a look at the model concept and thanks for your interest in my research. I will have a look at the Word document at length today. The model concept is the product of a larger study, the product of which is my M.Sc. thesis and I apologize for not having provided you with more information on the research itself. The information you suggest for further presentation of the model are of course discussed in great detail in my draft thesis, which is gradually being completed. The concept for the model will be used for the development of a computer based model for the settlement of Hanna Nassif. Hanna Nassif was chosen for the case study because of the wealth of research material and GIS data that was available on this particular settlement. The further development of the computer model, its calibration (which is an important step), verification, and validation will be focused on this settlement.

This, however, is somewhat the first step toward creating a much larger-scale model for the city (well at least those are the ambitions I have). What this study has done or is aimed to do is develop the concept which, if proven to work, can be adapted to this wider geographical area. The main difference would be the environment in which the model is implemented.

The ABM is aimed at serving as a tool for spatial planning as it should allow for prediction of land-use change under different scenarios, which I think can be achieved through the adjustment of the global parameters prescribed for the model. The visualization of results under varying scenarios can then help in decision-making regarding spatial planning (whether this is by conventional statutory planning measures or 'softer' instruments). I think it would also help to visualize the effects on spatial growth in the city if certain rural-based fiscal incentives or other poverty-alleviation strategies targeted at the urban population are employed. These should have an effect on some of the global parameters, which in turn affect the outcome of the simulation.

From the comments you provided in the email below, I have a question. Regarding the social network, my first supervisor has also questioned it's necessity. I thought perhaps it would be necessary if we consider that

incoming residents will not have complete knowledge of plot availability. In this sense the agents are said to exhibit 'bounded rationality' in that they make decisions based on the limited information made available to them. Through calibration of the computer model we might find it necessary to increase the spatial extent of this knowledge. However, do you think we should just remove the idea of this social network and have the agents choose a plot based solely on utility values, lot price, and socioeconomic structure of the neighborhood?
[VK] In principle, the inclusion of a social network variable to simulate bounded rationality does make sense. I only question its effect on the model outcome in this relatively small settlement and in competition with some strong variables. You should give it a try.

Regarding the comments on the macro variables, I do agree with you. In the first instance it would seem that the welfare associated with proximity to the main road is overestimated; both the bus stop and local market are accessible through the same exit. Then, the secondary roads may be overstressed as a factor due to the correlation with drainage. However, I have to keep in mind that this is the case of Hanna Nassif and while a few of these variables may become irrelevant during the development of the computer model, they may prove relevant when applying this concept to other settlements or this wider locale as I mentioned before (just a thought).
[VK] I fully agree.

Also, regarding the supply of potential owners by those residing in the settlement itself. I imagine this is the case now, but do you think this was the case historically? Unfortunately the development of the computer model has to be based on historical growth so that we can validate the simulation with real data. So I am just wondering if I should adjust this in the model. I was under the impression that in the past the owner population was mostly fed by incoming residents, based on the responses from the short survey conducted in October/November. I prematurely expressed this to my supervisor as well, so it would be good if I can make this necessary change at this point.
[VK] This is precisely the way I see it. In the infancy stage of settlement growth immigrants will play the leading part; later on the share of the sitting residents will increase. On Hanna Nassif you will probably find historical data in Prof. Kombe's dissertation which is hopefully available in the ITC library (Kombe, W. J.(1995): Formal and informal land management in Tanzania. The case of Dar es Salaam City. Dortmund (SPRING Research Series 13).

[DELETED TEXT]

Once again, thank you. Have a good evening.
Kind regards,
Gina Young

Annex 4: Tanzania Statistics

Tanzania inflation rates 1970-2004[11]

Year	Inflation Rate
1970	3.5
1971	4.7
1972	7.6
1973	10.5
1974	19.2
1975	26.5
1976	6.9
1977	11.6
1978	11.5
1979	13.8
1980	30.2
1981	30.3
1982	25.7
1983	28.9
1984	27.1
1985	36.1
1986	33.3
1987	32.4
1988	30.0
1989	31.2
1990	30.4
1991	28.0
1992	21.9
1993	23.6
1994	37.1
1995	26.5
1996	21.0
1997	16.09
1998	12.8
1999	7.89
2000	5.92
2001	5.13
2002	0.98
2003	3.54
2004	0.03

[11] Source: IMF, 2009; Nation Master: World Development Indicators Database, 2009

Annex 5: Social Network

Agent Interactions

The first set of agent interactions takes place through the environment where plot attributes such as agent utility and lot price are changed as plots are developed. These attributes further affect how incoming agents will interact with the environment (**Figure 6-2**). The second type of interaction among agents is through the creation of a social network that is initiated when an agent makes contact with a relative or friend for the location of an available plot; an example of this social network can be found in **Figure 6-3** below. Each established owner household is attributed with some knowledge of plot availability; this is represented by the initial 20 m[12] Euclidean distance in all directions. Agents become and remain linked even after the newcomers have settled. Because of this, the social network is expanded with each agent who enters the settlement and establishes a new house. The social network plays an important role in extending the spatial limit of the extent of knowledge on plot availability attributed to each established relative or friend. As time progresses the spatial extent naturally increases by Euclidean distance of 20 m through agent learning but it also increases through the social network. Therefore the set of available plot options for the incoming house owner increases with each time step. In the initial step the set of available plot options for an incoming agent is shown in **Figure 6-4**.

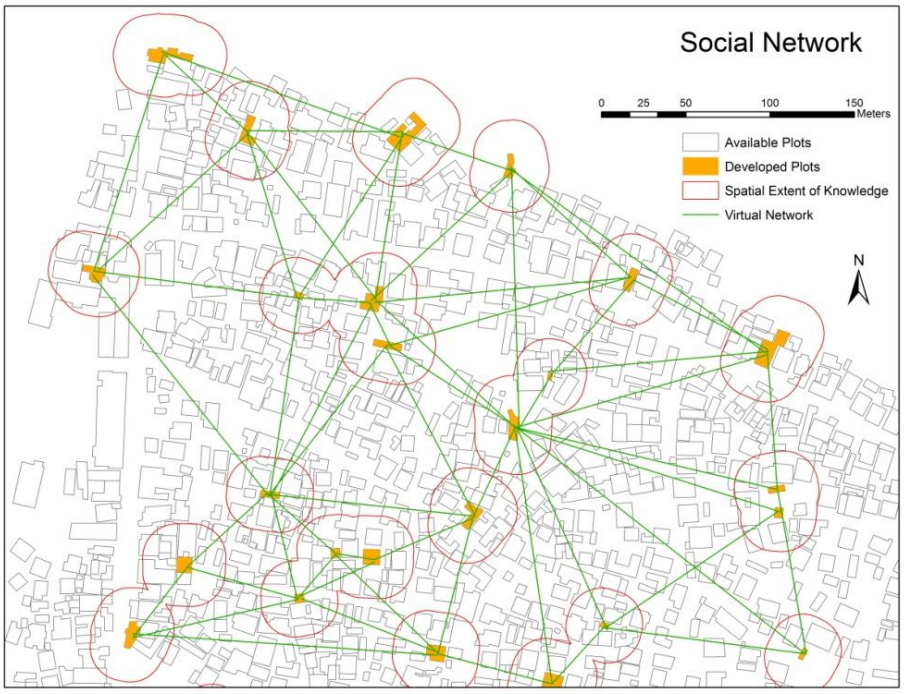

Figure 6-3: Social network example

[12] The initial and incremental 20 m suggested here is representative of the typical 20 m plot width found in this and other informal settlements in Dar es Salaam; however, calibration of the computer simulation may reveal the need to increase this distance.

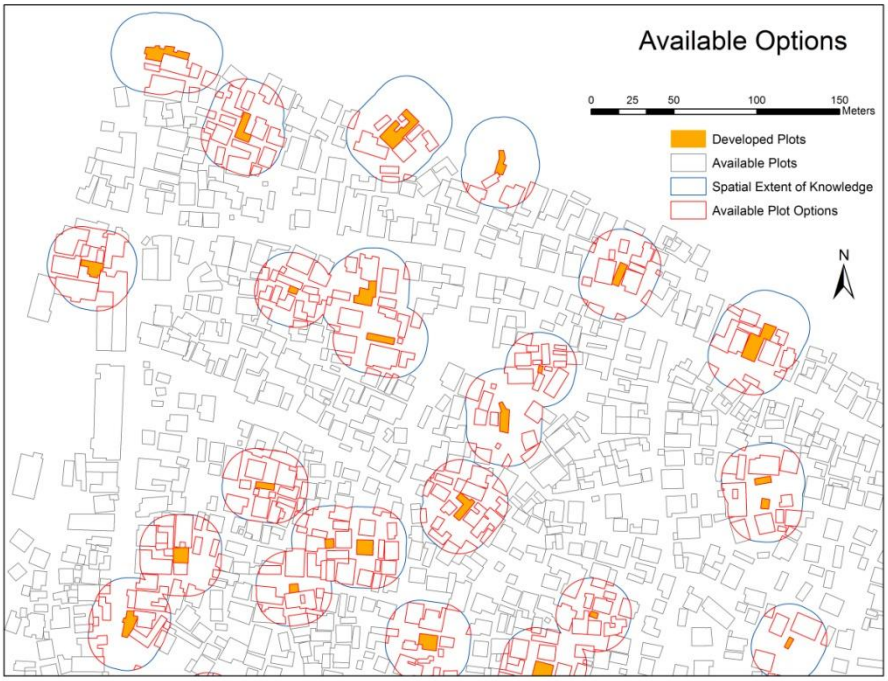

Figure 10-1: Available plots for potential owner agent

Learning module

The **learning module** starts here when the agent becomes an owner (**Figure 6-8**). It specifies the spatial extent of the agents' knowledge of plot availability and is increased at every time step by 20 m Euclidian distance in all directions. This information is used to update the agents' 'knowledge' attribute in the **agent transformation module** and is also fed into the **decision making module** as agents become part of the social network. Through learning the social network expands at every time step and thus the set of plots available to incoming agents increases. The initial and incremental 20 m suggested here is representative of the typical 20 m plot width found in this and other informal settlements in Dar es Salaam; however, calibration of the computer simulation may reveal the need to increase this distance.

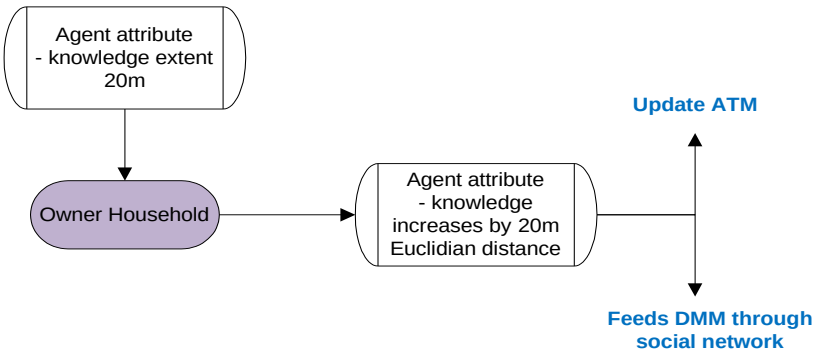

Figure 10-2: Learning module