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System dynamics approach to model the interactions among the factors of urban land allocation and people's well-being and satisfaction in city development

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Urban land allocation, planning, and management are complicated problems challenging decision-makers and policy writers all around the world. The multi-objective nature of the problem has engaged researchers to deal with the environmental, ecological, economic, social, recreational, commercial, and residential problems simultaneously, in any region, for better decision-making. These modelers neglected to consider people's satisfaction and well-being due to land allocation, planning, and development. Complex problems such as land allocation and planning require suitable integrated model building for solution and analysis. It was to this end that this author proposes a system dynamics approach for studying the impacts of the decisions made, by the policymakers in the long run, on the community' satisfaction using computer simulation. Taking one land allocation decision into consideration, the results of our proposed dynamic modeling point to the reality that people's level of satisfaction improves, their level of income enhances, and the quality of their lives increases with time. Satisfaction level improved from 36% to 48% during 10 years from 2010 to 2019. Well-being level also improves from 40% to 80% during the first 25 years and then stays at the same level until the end of the simulation period.

Key Words: *land management, policy making, system dynamics, simulation, people's satisfaction and wellbeing.*

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1. Introduction

Land management is a Worldwide phenomenon requiring a true understanding of the problem with the impacts that its mismanagement can have on its surroundings. Usually, researchers use multi-objective modeling of the problem taking environmental, ecological, economic, social, recreational, commercial, and residential requirements into consideration. Complex problems such as land allocation and planning require suitable integrated model building for solution and data analysis. Several researchers such as Chang et al. [14] used operations research and applied mathematics for model development and situation analysis. The importance of this problem has attracted the attention of many researchers in the simulation field as well. Traditional system dynamics (SD) have been employed for such problem analysis by some researchers: Francisco et al. [27], Masoumi et al. [48], Costanza et al. [71], and Cavallaro & Ciraolo [13]. Thereafter, other researchers took steps in this direction to enrich the field under consideration. These researchers are Guan et al. [38], Gao et al. [28], Gu [29], Chen et al. [17], and Chang et al. [16].

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Knowing that some researchers conducted studies on land management, land planning, and land allocation, few have considered the impacts of land management on community satisfaction. Demonstrating the dynamic trend of community satisfaction by year is highly regarded by the management and the entire community as they see the impacts of the policies implemented on their life. The nature of the land allocation problem has directed this author to employ a system dynamics approach for modeling and simulation to demonstrate the community's satisfaction, income rate, life quality, and people's welfare.

This article is organized as described below: Section 2 discusses the research background which is comprised of land allocation and planning, and backgrounds on system dynamics and client satisfaction. Gap analysis and research objectives and methodology are discussed in section 3. Modeling of the problem is discussed in section 4. Section 5 is devoted to the System Dynamics model of the problem. Mathematical model development for simulation is the topic of section 6. Indices evaluation is discussed in section 7 while model assessment is discussed in section 8. Scenario development is the topic of section 9. Managerial implementation is discussed in section 10. While theoretical implications, software implications, and policy implications are discussed in section 11. The conclusion is given in section 12.

2. Research Background

This section is devoted to the background topics on land allocation and planning, system dynamics, and customer satisfaction.

2.1 Land allocation and planning

For land planning purposes, different goals such as economic, social, and environmental are usually considered. Fast economic development and social constant changes occurring in the community are the main reasons that new approaches to land management and allocation come to the surface. For having a logical approach to land allocation, making a balance among all contrasting objectives is the most considered in the literature. People's participation in the process of planning is also very important. Different approaches to land planning and allocation are taken into consideration by researchers all around the world. Potter and Nortcliff [58] concentrated on the topic of “Ever growing Amman”, Jordan. The authors discussed urban expansion, social polarization, and contemporary urban planning. The employment and industrial bases of the city and a range of important issues such as transportation, traffic congestion, water stress, and urban and regional developments are also taken into consideration. Approaches such as goal programming used by Ignizio et al. [37], and Genetic Algorithm by Shaygan et al. [64]. Fooks et al. [23] researched maximizing conservation and minimizing cost share using goal programming for forest protection. Other researchers employed Simulated annealing (Aerts [1]) and genetic algorithms to solve some larger-size problems. Other works in the area of land use planning are related to the research conducted by Pan et al. [59], Pahlavani et al. [60], Priyadarisini [61], and Pan et al. [62].

Yang et al. [76] employed a simulated intra-urban land use dynamics model in Jinzhou area to simulate using fuzzy cellular automata to determine all factors influencing urban land use change. For this purpose, land use data from multiple sources and remote sensing images from 2003 to 2015 were analyzed. Huang and Chen [36] studied the interactive behavior of sustainability indicators using an urban systems model consisting of six subsystems of land use, population, transportation, water resources, solid waste, and wastewater. The authors developed fourteen urban sustainability indicators for Taipei as a case study area. STELLA software was used to simulate the changes in indicators over time. Waddell et al. [74] have conducted several studies using micro-simulation of urban development. In their article (2002), the authors stated that "UrbanSim is a new urban simulation model, developed over the past several years, which is now operational in three urban areas in the United States. The model system is designed to address emerging needs to better coordinate transportation and land use planning as a result of recognition of the strong interactions between land use and transportation, increasing pressure from federal transportation and environmental legislation, and growing adoption of state growth management programs In their article, Moeckel et al. [49], claimed that "micro-simulation modules will include models of demographic development, household formation, firm lifecycles, residential and non-residential construction, labor mobility on the regional labor market and household mobility on the regional housing market." Velásquez et al. [39] presented a mathematical model to study regional planning in a city. This approach considers the economic area as well as the logistics and the land use. The mathematical modeling considers factors such as population growth, zoning, geographic mapping, employment, land supply, urban and rural freight flows, allocation of healthcare, education, public space, and other social services, and the analysis of the outcomes of land use.

Chen et al. [17] have studied the management of land availability in the river basin. The authors have concentrated on the sustainable management of land and its appropriate utilization. Chang et al. [16] have proposed a decision support system for sustainable system management. Their process of decision-making is composed of three levels: (1) physical level, (2) SD modeling level, and (3) decision-making level. The middle-level modeling comprises socio-economic, environmental, management, and ecological subsystems. Concerning public policy and resources, Brent et al. [11], explored the utilization of system dynamics in South Africa. Currie et al. [20] applied system dynamics modeling to environmental health problems and policymaking. Ramazanian and Hajipour [63] proposed an integrated framework of system dynamics and meta-heuristic for multi-objective land use planning problems. Shen et al. [65] have proposed a system dynamics model for sustainable land planning, development, and utilization. This model is proposed for city development and sustainable land usage in the city of Hong Kong. The subsystems used are population, housing, economic, transportation, and urban land areas. Han et al. [35] proposed an integrated system dynamics approach for analyzing the economic driving forces as well as social demands and management of the spatial city of Shanghai. Liu et al. [44] have used a combination of system dynamics and PSO algorithms to determine how land should be allocated. This approach is comprised of two distinct parts SD and PSO. The SD portion of the modeling is used for studying various scenarios which are parameters such as population, economics, technology, and local or national politics. The optimization portion of the modeling deals with suitability, compatibility, compactness, and spatial distance. These features are taken into consideration as the four objectives of the problem. Chung and Ko [15] have proposed an interactive dynamic multi-objective programming (IDMOP) model to make decision-makers a part of the solution process. This is a compromise modeling approach considering uncertainty. This IDMOP considers four objectives. These objectives are economic development maximization, pollution minimization, job opportunities maximization, and Dioxide carbon minimization. Table 1 shows a list of articles related to land allocation, planning, sustainability, resiliency, and management. This is a portion of the literature on this topic, however. Our research on this subject indicates that there is no study available that relates land planning and allocation to residential satisfaction and people's well-being as considered in this article.

Table 1: Land planning and management

Row	Subject	Solution Approach	Authors
1	Simulating Intra-urban Land Use Dynamics under Multiple Scenarios Based on Fuzzy Cellular Automata	Simulation approach	Jun Yang ,Weiling Liu,Yonghua Li, Xueming Li, and Quansheng Ge. (2018) [76]
2	A system dynamics approach to the simulation of urban sustainability	SD	S.-L. Huang, C.-W.Chen. (1999).[36]
3	Microsimulation of Urban Development and Location Choices	Micro Simulation	Waddell, P., A. Borning, M. Noth, N. Freier, M. Becke, G. Ulfarsson. (2002) [73]
4	Micro simulation of land use	Micro Simulation	Rolf Moeckel, Klaus Spiekermann, Carsten Schürmann, Michael Wegener (2003) [49]
5	A combination of system dynamics and PSO algorithm	SD and PSO	Liu et al (2013) [44]
6	An interactive dynamic multi-objective programming (IDMOP) is used.	Interactive and MOP	Chung and Ko (2014) [15]
7	An integrated system dynamics approach	SD	Han et al. (2009) [35]
8	A system dynamics model for sustainable land planning, development, and utilization	SD	Shen et al. [65]
9	A decision support system for sustainable coral reef management.	DSS	Chang et al (2008) [16]
10	Management of land availability at the river basin	Managerial approach	Chen et al. (2005) [17]
11	New approaches to land-use planning	Planning	A. Moghaddam, Farahara Nowrouzi, (2000) [50]
12	Multi-objective land use planning problem	MOP	Ramazaian, R. and Hajipour, M. (2020)[61]
13	Urban problems and patterns of change: The analysis of a downgraded industrial area in Turin	SD	Bottero, M.; Caprioli, C.; Berta, M. (2020) [7]
14	A System Dynamics Model and Analytic Network Process: An Integrated Approach to Investigate Urban Resilience	SD	Marta Bottero , Giulia Datola and Elena De Angelis, (2020) [9]
15	Modeling and dynamic assessment of urban economy-resource-environment system with a coupled system dynamics	SD	Guan, D.; Gao, W.; Su, W.; Li, H.; Hokao, K, (2011) [32]
16	Land-use spatial optimization model based on genetic optimization and game theory	GA	Liu, Y.; Tang, W.; He, J.; Liu, Y.; Ai, T.; Liu, D. A (2015) [42]
17	Land-use scenario modeling based on human decisions–combining system dynamics and cellular automata,	SD and Cellular-Automata	Lauf, S., Dagmar Haase , Birgit Kleinschmit, (2012)[41]

18	Households matter: the quiet demography of urban transformation	Demographic analysis	Buzar, S., P. Odgen, and R. Hall, (2005) [12]
19	Applying social science concepts: Modeling and simulating residential mobility in a shrinking cit.	Simulation approach	Haase, D., S. Lautenbach, and R. Seppelt, (2010) [34]
20	Urban regions, ecology, and planning beyond the city	Urban planning	Forman, R.T.T. (2008) [24]
21	Introduction to urban dynamics. Pegasus Communications: Waltham, MA.	Urban analysis	Alfeld LE, Graham AK. (1976) [2]
22	An interactive dynamic multi-objective programming model to support better land use planning	MOPM	Yang-Chi Chang, Tsung-Ting Ko, (2014) [15]
23	Using simulated annealing for resource allocation	SA	Aerts, et al., Heuvelink, G.B.M. (2002) [1]
24	A Mathematical Programming Model for Regional Planning Incorporating Economics, Logistics, Infrastructure and Land Use	Optimization	Jesús Velásquez, Carolina Saldaña, and Edgar Gutierrez-Franco (2017) [39]
25	The application of system dynamics modeling to environmental health decision-making and policy-a scoping review	SD	Currie, D., Smith, C., Jagals, P. (2018) [19]
26	Dynamic assessment of urban economy-environment-energy system using system dynamics model: A case study in Beijing. Environ	SD	Wu, D.; Ning, S. (2018) [76]
27	Urban problems and patterns of change: The analysis of a downgraded industrial area in Turin	Multi-Criteria Analysis	Bottero, M.; Caprioli, C.; Berta, M. (2020) [7]
28	Measuring the Disaster Resilience of an Urban Community Using ANP-FCE Method from the Perspective of Capitals	ANP-FCE	Cui, P.; Li, D. **2019 [18]**
29	Systems Thinking: System Dynamics. In System Dynamics: Modelling and Simulation; Springer Singapore: Singapore	SD	Bala, B.K.; Arshad, F.M.; Noh, K.M. (2017)[5]
30	System dynamics models for the simulation of sustainable urban development: A review and analysis and the stakeholder perspective.	SD	Pejic Bach, M.; Tustanovski, E.; Ip, W.H.; Yung, K.; Roblek, V. **(2020)** [55]
31	A system dynamics model for simulating urban sustainability performance: A China case study	SD	Tan, Y.; Jiao, L.; Shuai, C.; Shen, L. (**2018**) [72]
32	Modeling the dynamics of urban development project: Focusing on self-sufficient city development	SD	Park, M.; Kim, Y.; Lee, H.S.; Han, S.; Hwang, S.; Choi, M.J. **(2013) [54]**
33	Dynamic analysis of resiliency and sustainable production system	SD	Zare Mehrjerdi, Y. (2023) [78]
34	An integrated evaluation methodology to measure ecological and economic landscape states for territorial transformation scenarios: An application in Piedmont	Integrated approach	Assumma, V.; Bottero, M.; Monaco, R.; Soares, A.J. **(2019**) [4]
35	Exploring urban resilience thinking for its application in urban planning: A review of	Literature Review	Masnavi, M.R.; Gharai, F.; Hajibandeh, M.

	literature.		**(2019)** [46]
36	Strategic assessment and economic evaluation: The case study of Yanzhou Island (China)	NPV	Bottero, M.; Comino, E.; Dell'Anna, F.; Dominici, L.; Rosso, M. (**2019) [10]**

2.2. System dynamics

An approach known as system dynamics is a sophisticated methodology for modeling complex problems, such as land planning and management. When a system requires optimization and no feedback loops is associated with that then optimization can help the modeler to optimize the system. When feedback loops must be used to show the interrelationships among some variables of the problem then the use of system dynamics is an alternative way. The problem of land allocation and planning along with the community satisfaction study is the one that deals with feedback loops and hence demands the system dynamics use.

System dynamics (SD) that is originally developed by Jay W. Forrester in 1950 is one of the best tools for analyzing complex systems. In his pioneering research on the subject of production and distribution, urban dynamics, industrial dynamics [25], and world dynamics [26], Forrester showed the system's oscillatory behavior. Then, he discussed policies to improve the performance of the system under study and how policy-making instead of decision-making is possible using the SD approach. Since he demonstrated various policy experimentations on this kind of problem that he has proposed other researchers were encouraged to employ system dynamics as a tool for policy making. Researchers used SD to represent relations existing among system variables such as the rates of change over time and the accumulation of values using stock variables. Feedback does play a key role in capturing complexity into the system of the problem. The modeling approach is of integration type rather than individual transaction management. This type of modeling is used only when we want to relate rate variables, stock variables, auxiliary variables, and fixed factors together. System dynamics modeling is more often associated with higher-level types of problems, especially consideration of the impact of policy and strategy decisions. Madani and Mariño [47] conducted research on Iran's Zayandeh-Rud river basin using system dynamics approach.

2.3. People Satisfaction

People satisfaction is a criterion for determining the level of quality of goods and services that an organization produces. Customer satisfaction is a highly regarded index for corporations and allocation-type management. There are ways to measure satisfaction, however. Berkman and Gilson [8] claimed that "satisfaction reinforces positive attitudes toward the brand, leading to a greater likelihood that the same brand will be purchased again. It is often said that "satisfaction of customers" is the cheapest means of promotion. Knutson [40] says that this ratio ranges from 10 to 1 while Naumann [52] uses 5 to 1 from satisfied to dissatisfied customer. There are nine theories available in the literature that point to customer satisfaction as researched by Pizam and Ellis [56, 57]. These theories, some of which were never put into the empirical research, are: (1) expectancy disconfirmation, (2) assimilation or cognitive dissonance, (3) contrast, (4) assimilation contrast, (5) equity, (6) attribution, (7) comparison level, (8) generalized negativity, and (9) value precept. Some researchers have applied customer satisfaction theories to various areas such as lodging [6]), food services [3], and hospitality enterprises [56]). As Parasuraman et al. [53] indicate, one way to measure service quality is by subtracting customer perception scores from customer expectation scores (Q = P - E). The greater the positive score represents the greater the positive amounts of service quality or vice versa [56, 57]. Tools to measure customer satisfaction are linear programming [43], and cost-benefit analysis known as B/C. A trend in customer satisfaction by duration (months, or years) can be determined using the system dynamics approach. Zagonel et al. [77] conducted research on welfare using simulation models to address "what if" questions about welfare reform. Zare Mehrjerdi [79] studied organizational strategy development using MADM and risk-benefit analysis in a fuzzy environment. Mortazavi et al. [51] identified the effective factors in personal branding in the food industry based on the grounded theory method.

3. Gap Analysis

Using Table 1 as a source of information and what we have discussed in sections 1 and 2, before, the research gap can be stated as below:

(1) land allocation and planning as a means of improving the level of community satisfaction, welfare, and income generation has not been studied in the past.
(2) Such a comprehensive and integrated model is a complex system that demands special care and studying.
(3) system dynamics as a tool has not been employed for solving such an integrated complex problem.
(4) There is no similar research available as the review of literature on the subject matter indicates. Table 2 shows the place of contribution of this article and the similarity between this work and previously presented articles in the literature.

Table 2: Reported studies with MCDM methods in association with Land planning and allocation

	MADM approaches	MODM approaches	System Systemic and simulation approach	Integrated MCDM and System dynamics
(1) Land planning using Portfolio type management idea	X	Gibert, et al. [31], Chang and Ko [15], Stewart, et al. [67]	System dynamics (this study)	Chang and Ko [15]
(2) Land planning and Community Satisfaction	X	X	System dynamics (this study)	X
(3) Land planning and Community wellbeing	X	X	Systems thinking, SD (this study)	X
(4) Land planning and Job development	X	X	Scenario analysis through SD (this study)	X
(5) Land planning and City development	X	Gulen et al. [33]	SD (this study), Gulen, et al. [33]	X
(6) Dynamic analysis of integrated (1)-(5) above situations	X	X	This study	X
(7) Urban development and self-sufficiency	X	X	Park, et al. [54] Zhan, et al. [54]	X

Hence, the purpose of this study is to develop a system dynamics model that can assist managers in determining the level of people's satisfaction, welfare, and income that is generated due to land development, land allocation, and management. The fact that land allocation to industries, and businesses can finally lead to new jobs, and jobs can produce incomes for people and incomes can lead to the well-being of families in the community, will make great changes to the community level of satisfaction. None of the previous researchers have looked at the problem in such away yet. For this reason alone, this research makes an important contribution to the study of land management methodology.

To conduct this study, the author identified following steps for completing this research: (1) determining urban community factors using the concepts of land development and management, along with principles of systems thinking; (2) producing causal loop diagram (CLD) using factors identified in step 1; (3) constructing stock and flow diagram using CLD; (4) formulating the problem using the fundamental concepts of SD modeling by employing rate variables, state variables, artificial variables, and constant parameters, within the scope of Vensim computer software; (5) simulating the model of problem using predefined values for the parameters and initial values for the state variables; and (6) scenario development and analysis. Figure 1 presents these steps graphically for clarification purposes.

4. Modeling the problem

Imagine a small town, with a population of less than one hundred thousand, is the case understudy here. The town has residents with very low community satisfaction levels due to being environmentally surrounded by a wide arid region and sandy desert and not having an acceptable rate of growth historically. This city (Community A) has competed with a similar size and environmental conditions town (Community B) which is located by the side of the Silk Road and passes from the North to the south of the country. Community A is very unsatisfied with the local policymakers. Hence the level of satisfaction of the community is predicted to be 15% as long as history speculates.

Since road construction for community A, just to satisfy this community, is both very costly (1) money-wise for the state and (2) economically soundless, community expansion and land planning were considered to be an alternative. Taking this strategy into consideration, it may have significant impacts on the city expansion, land value, and people's income level and welfare due to that. The question is how much this strategy will have an impact on community satisfaction levels and make people reside in their own two rather than migrating to larger cities in the country. Note should be given that there are many small towns country-wise that are facing similar problems. This is because misfortunate towns do not have the chance of growth both socially and economically, therefore these people stay poor and not being competitive under any circumstances.

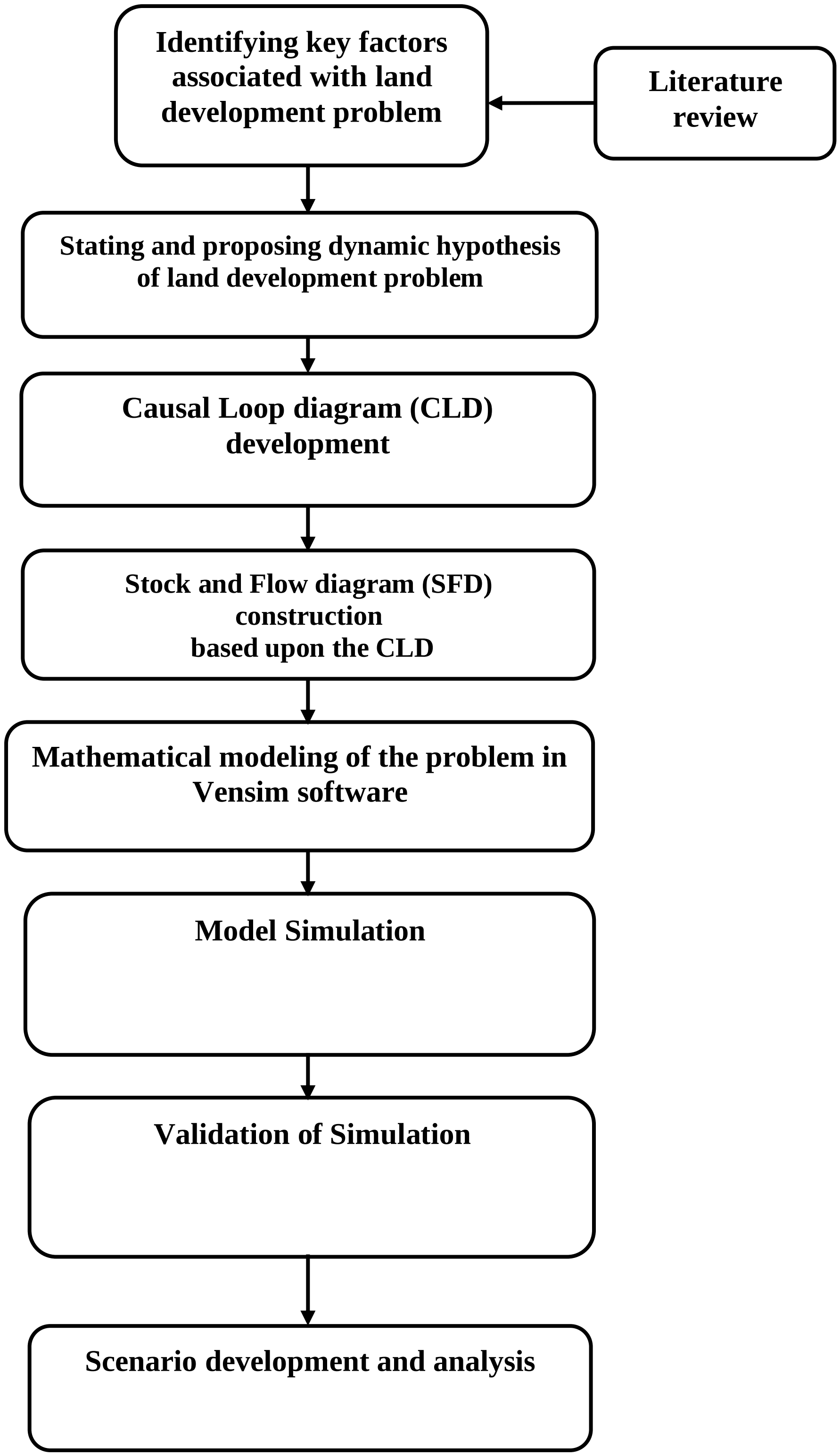

Figure 1: Steps to follow Land development study using system dynamics

4.1 System's border

The boundary of a system is an imaginary thing that can be defined by a system analyst for modeling the problem. This boundary must be as exact as possible. It might not always be the case, however. Usually, in system dynamics, a model boundary is defined by a table consisting of variables known as endogenous variables, exogenous variables, and discarded variables. For our land development system, these variables are defined by Table 2.

Table 2: Variable classification as endogenous, exogenous, and omitted

Endogenous Variables	Population	Request for cultural centers
	Net population rate	Available land for city
	Immigration population	Level of Satisfaction
	Housing construction	Satisfaction rate
	Land request for housing	Life quality level
	Land allocation for housing	People welfare
	Rate of request for housing	Incomes
	Housing numbers (counts)	Jobs
	Housing shortages	People's participation
	Current land price	People's convenience
	Request for city development	Number of business enterprise
	Request for business development	Land for industrial use
	Request for recreation	Land for new facilities in the city
Exogenous Variables		
	Birth rate	
	Land price	
Omitted Variables		
	Sewage planning	
	Water reservoirs	
	Utility centers	
	Transportation hubs	
	Pollution	
	Inflation	
	Community polices	
	Cultural center	
	City growth rate	
	Road construction	

4.2. Causality and Feedback Loops

There are various ways to develop a causality diagram as discussed in books by Sushil [70]. To build such a diagram, after identifying a complete list of the variables representing the endogenous system's variables, one starts by using two variables A and B from the list. Then, the relationship between them needs to be examined. We must think of the influence of using an arrow to represent that. This arrow starts from A and ends at B when we think of the impact of variable A on variable B. This concept can be reversed once we take into consideration the impact of variable B on variable A. More details of this concept can be obtained from the work of Sushil [70] and Sterman [66]. A diagram that can show the cause and effects relationship between two factors of "Land request for housing" and "Land allocation for housing" can be demonstrated below (Figure 1).

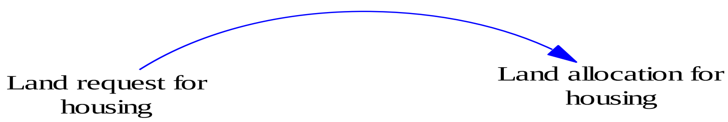

Figure 2: an arrow

Using Figure 2 two things can be deducted:

- "Land request for housing" and "Land allocation for housing" are the elements of this model.
- Land request for housing" influences "Land allocation for housing" in the same (+) direction as "Land request for housing". This means that as "Land request for housing" increases the level of "Land allocation for housing" also increases.

Two types of feedback loops known as "reinforcing loop" and "balancing loop" are used in model development, in general. The feedback loops are the main cause of dynamic behavior of the system. Figure 3 is comprised of two reinforcing loops of Loop1 and Loop2 and one balancing loop of Loop3. The balancing loop goes through five variables of "Housing counts available", "Rate request for housing", "Land request for housing", "Land allocation for housing", "Housing construction", and "Housing counts available".

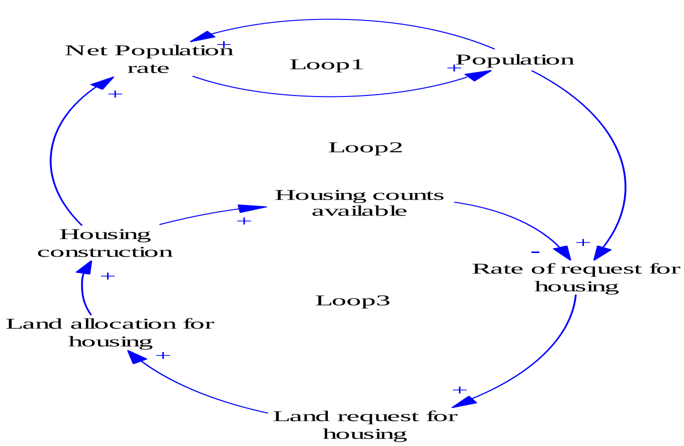

Figure 3: Feedback loops

4.3 Dynamic hypothesis

The dynamic hypothesis is a depiction of a cause-and-effect diagram showing important feedback loops and main variables and/or subsystems of the problem. The model hypothesis for portfolio-type land management systems for city development is presented in Figure 4. Five basic loops are used here where each describes the land assignment to one type of request only. Each time land is allocated to a request, the total available land decreases and it causes less land to be available for assigning to another purpose, for instance to the housing sector. This hypothesis is used in the remaining parts of this article for model development and result analysis. This means that:

Land available for housing = {Total land available for allocation } –
{Land allocation for city development} –
{Land allocation for business centers} –
{Land allocation for recreation } –
{Land allocation for cultural center} (1)

Mathematically, this means that if X_i represents the percentage of land allocation to each of the cases described in the above formula then the following formula holds:

$$X_1 + X_2 + X_3 + X_4 + X_5 = 1 \quad (2)$$

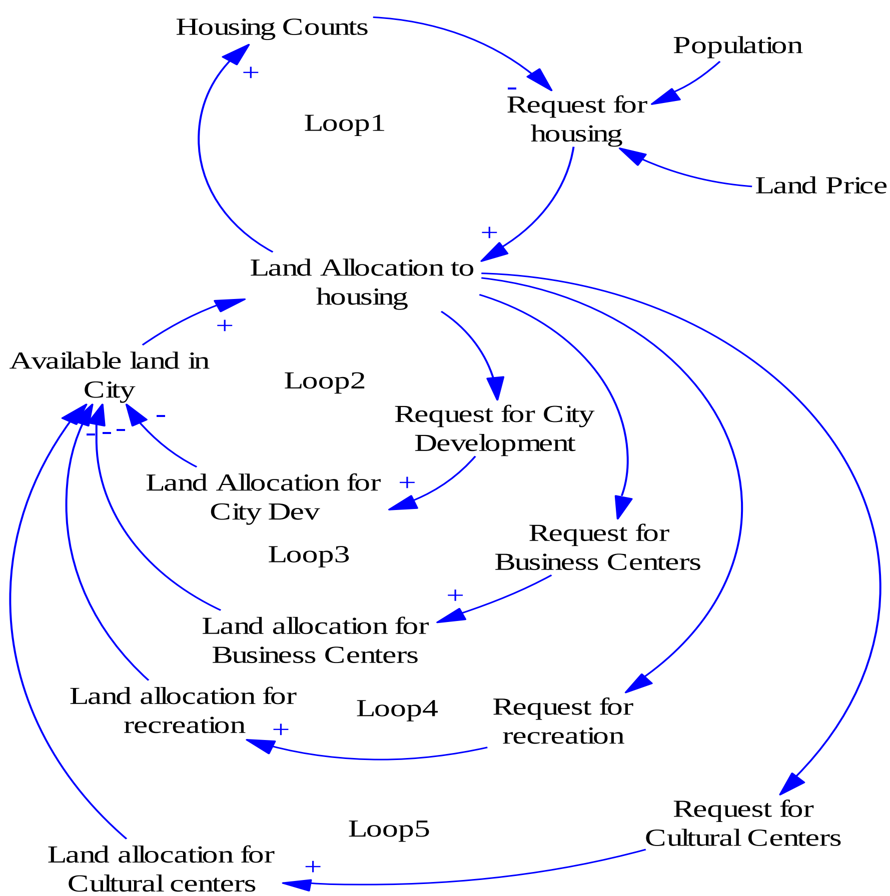

Figure 4: Dynamic hypothesis for portfolio type land management system for city development

5. System Dynamics model of the problem
5.1 Land assignment for housing

Systematic thinking means every action may be considered with both cause and effects phenomenon. There is no one-sided action (Senge, 2016). Causal links between variables are assigned a positive (+) or negative (-) sign indicating polarity. A positive sign means that cause and effect changes are in the same direction, and a negative sign means the opposite direction of cause and effect changes. The feedback process is divided into two distinct types: reinforcement and balancing. Many factors have significant roles in assigning land to different sectors for city development. One of these factors is population. Other important factors are listed in Table 2. One of the factors that are really in need of paying attention is the city growth rate. Population is a factor that increases the rate of demand for land assignment to housing. Once the population increases then the housing shortages will increase. The housing shortages and the request for land for housing caused city managers and policymakers to allocate sufficient land for housing construction. Housing shortages cause fewer people from rural areas to come to the city for settlement. But, jobs in the city are a big factor in attracting people from other parts of the country. Taking Figure 5 into consideration, we notice that six factors have direct impacts on housing request rates. These factors are (1) population, (2) housing shortages, (3) current land price, (4) residence income, (5) land request for housing, and (6) new population inflow.

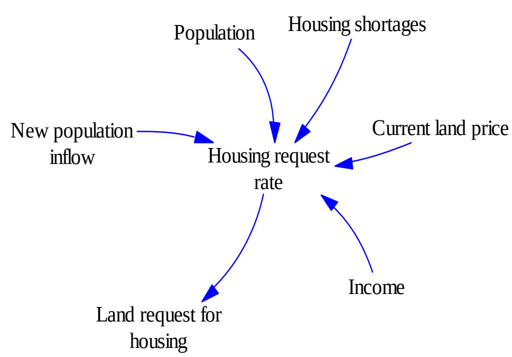

Figure 5: causal loop presentation for housing request rate

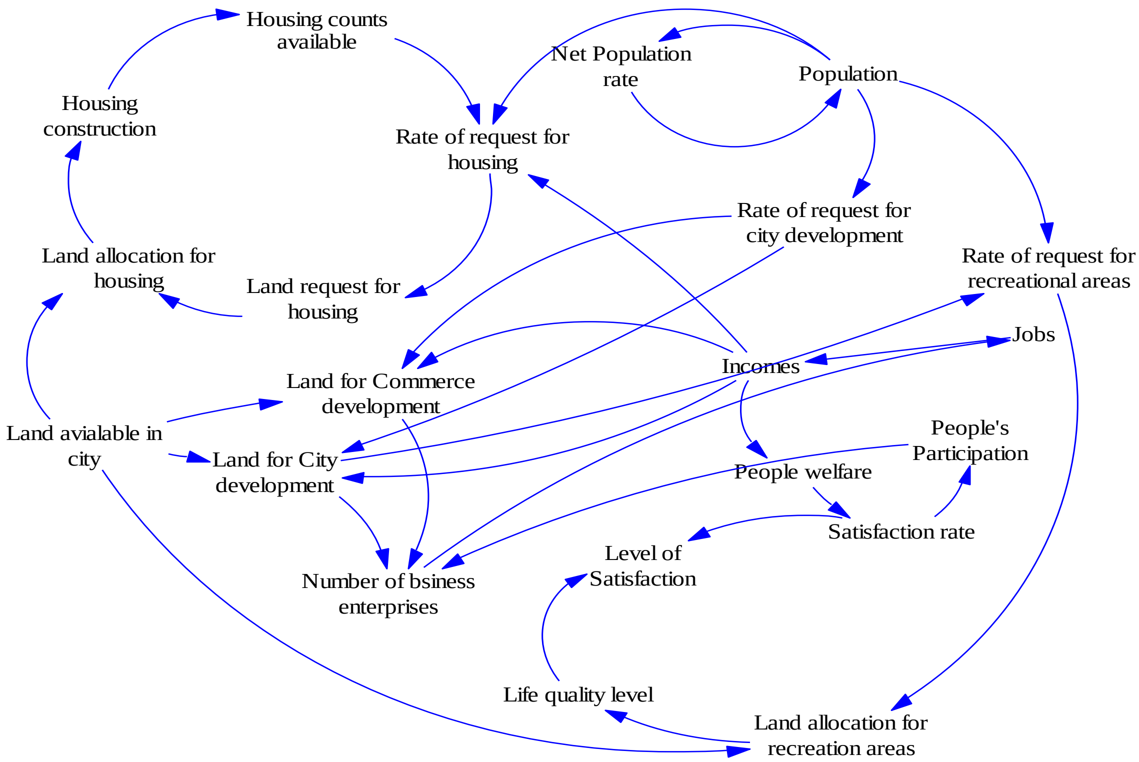

Figure 6: a causal loop presentation for city development including land allocation

As it is shown in Figure 6, increases in the “Net population rate” cause the level of “Population” to increase. This increase in population causes the “Rate of housing requests” to increase. As a result of this, “Land request for housing” increases, which leads to increases in “land allocation for housing”? Once “land allocation for housing” increases the “housing construction” increases. This would lead to “Housing counts available”, which leads to people's attraction to the city, and hence the increase in “Net population rate.

5.2 City development

City expansion and development become a necessity as the city population grows and more land allocated to housing becomes necessary. City developments need land for road construction, street building, public parking lots construction and etc. Using the causal diagram 6, we can create the stock and flow diagram presented in Figure 7 for this problem.

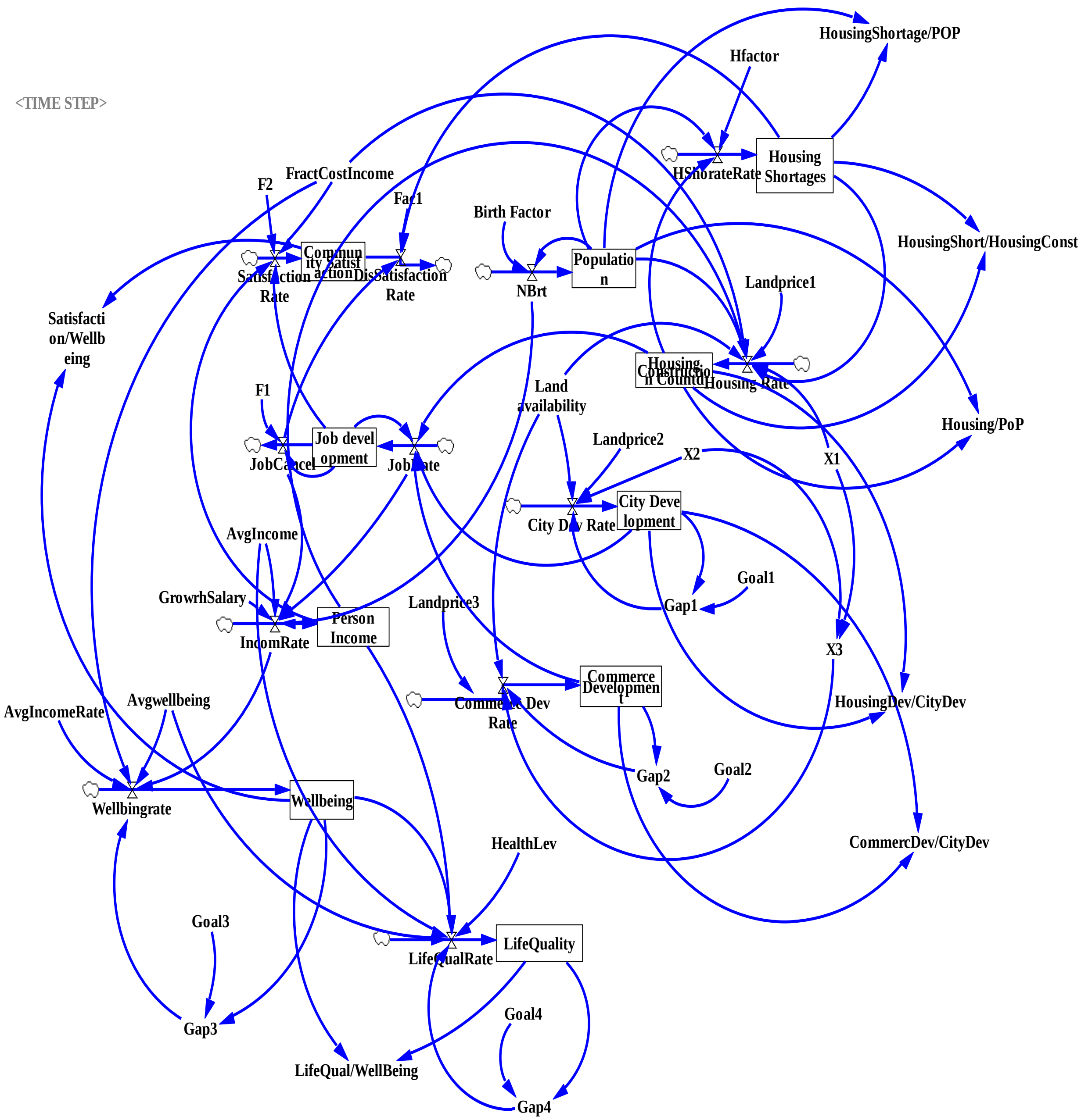

Figure 7: Flow diagram presentation of causal loop

5.3. Description of feedback loops and variables

Table 3 describes all feedback loops one by one and the factors used in each loop and what each loop is standing for. Table 4 describes three classes of variables and the variables associated with each class as they were used in the model building.

Table 3: Feedback structures with the description of some of the loops

Loops	Variables in the loop	Description
Loop 1	Loop Number 1 of length 4: Total Income, Commerce Dev Rate Commerce Dev, Number of Businesses, Income Rate, Total income	This loop indentifies those variables that play role in income generation as far as this model is concerned.
Loop 2	Loop Number 2 of length 6: Total Income, City Dev Rate, City Development, Commerce Dev Rate, Commerce Dev, Number of Businesses, Income Rate	This loop relates city development phenomenon with the number of business and then with the commerce development as well
Loop 3	Loop Number 3 of length 6: Total Income, People welfare, Satisfaction rate, People Satisfaction, People participation, Number of Businesses, Income Rate	This loop relates income to the welfare and the satisfaction rate of the people.
Loops 4 and 5	Loop Number 4 of length 7: Total Income, Life Quality rate, Life Quality, Satisfaction rate, People Satisfaction, People participation, Number of Businesses, Income Rate	This loop identifies those variables that play role in the life quality, satisfaction rate and people's participation
Loop 5	Birth factor, Population and NBrt Rate	This loop is about the population and its related variables.

Table 4: Potential variables for SFD

Class	Variables
Level Variables	Population Housing Counts City Development Commerce Dev Total Income Life Quality People Satisfaction
Rate Variables	Net Birth rate (NBrt) House rate City Dev rate Commerce Dev rate Income rate Life Quality rate Satisfaction rate
Supplemental Variables	Birth factor Land available Land Price Number of Businesses X1, X2, X3 f1, f2, f3, Wf4, Qf5

6. Mathematical model development for simulation

Once stock and flow are developed based upon the causal diagram then it is time to generate the mathematical model of the problem for simulation. A simple example problem shown in Figure 8 takes one state variable called Stock and two rate variables called Rate1 and Rate2 into consideration. Rate1 and Rate2 have positive and negative effects on the Stock variable, respectively. To calculate the value of Rate1 and Rate2 we use the following formulas:

$$\text{Rate1} = \text{factor1} * \text{Stock}(t-1)$$
$$\text{Rate2} = \text{factor2} * \text{Stock}(t-1)$$

$$\text{Stock} = \int (Rate1 - Rate2)dt$$

The process of simulation is as shown below:

Stock (t) = Stock (t-1) + dt * (Rate1 – Rate2)

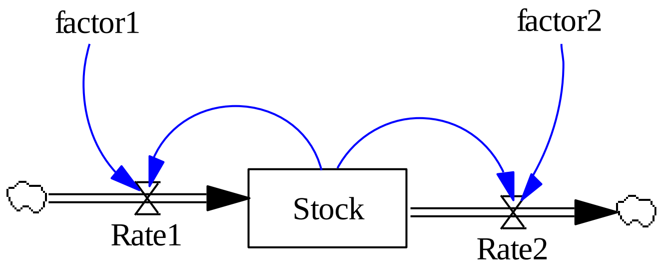

Figure 8: Stock flow diagram

The model developed in this section is comprised of seven level variables (1) Population, (2) Housing Counts, (3) City Development, (4) Commerce Dev, (5) Total Income, (6) Life Quality, and (7) People Satisfaction. The simulation model developed here studies these variables and provides a trend for each one separately. We discuss the model in more detail in the sections that follow.

6.1 Housing counts

Land may have different uses with time as such as land for farming, land for housing or land for building new shopping centers. There are so often than not, these types of usage of one piece of land occur in a community. These kinds of usage of land can have different impacts on the environment and the people living in that community. Analysts should look at this problem systematically and the related cause and effect variables reciprocally to see all possible impacts. This sort of look at the problem will generate nonlinear impacts of variables on each other as the loop works for a while. Due to the fact that complex problems deal with many closed loops therefore the nonlinearity impacts and unpredictability of the goal variables behavior may become less clear to the analyst and decision makers.

The social behavior of people as well as the number of them in one community can have serious impacts on the demand for housing and hence the kind of land usage in one community The household structures can be considered as: the house for the smaller family, house for couples with child, house for childless couple, and house for single, which has changed considerably from house for large family in the past. These sorts of new expectations for housing can have significant impacts on the house counts in one community. This means that the mean house size is decreasing while the household numbers are increasing. Therefore, city managers of each community need to predict such social behavior of people and what they really expect from them in the long run. In addition to population and social behavior as discussed, people's income, land price and land availability are also playing significant role in demand for housing. This article highlights the impacts of population, total income, land availability, land price, and land allocation to housing rate. House rate have impact on the house counts that would be available for housing the residents. Figure 9 demonstrates those factors that have impacts on house rate and consequently on the house counts.

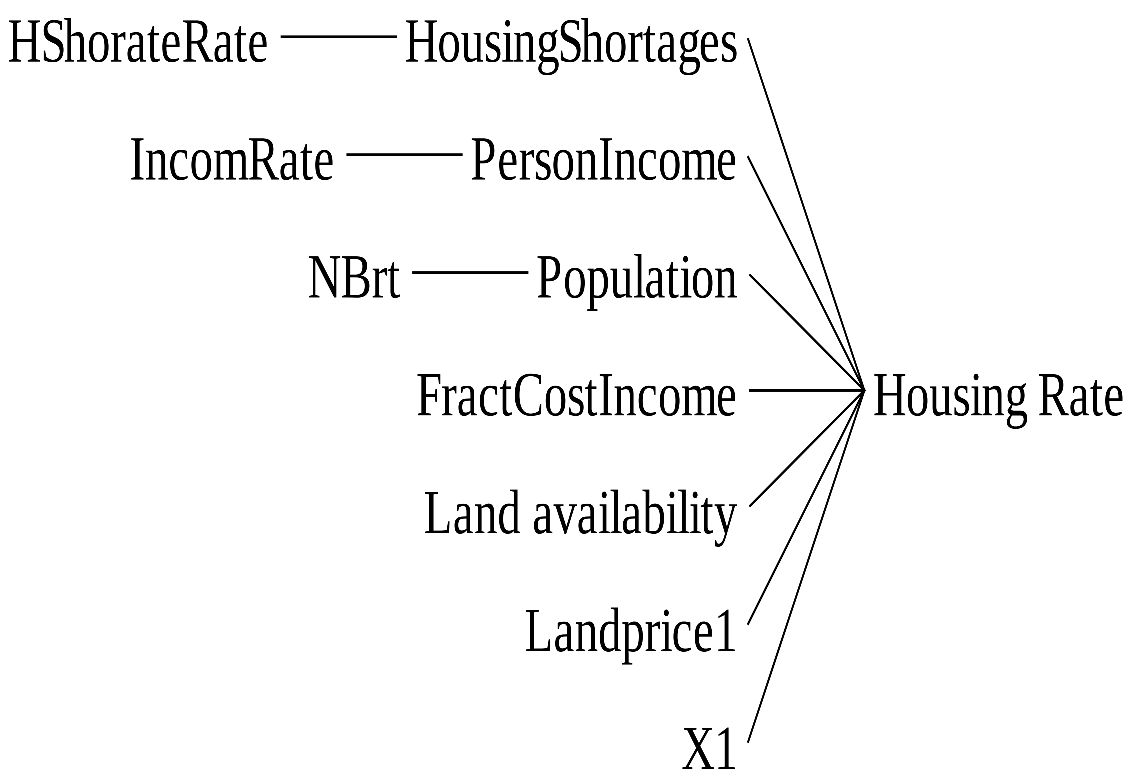

Figure 9: Housing counts rate related factors

6.2 Commerce development

Anywhere people have built the houses businesses have come to set up stores and sell their products. City development and its rate of growth, and community mid income size are the driving force for new commerce developments. Price for land, land availability and allocation are other driving forces for commerce development. The availability of jobs and housing leads to growth in the population via migration. Figure 10 demonstrates those factors that have impacts on commerce development rate and consequently on commerce development.

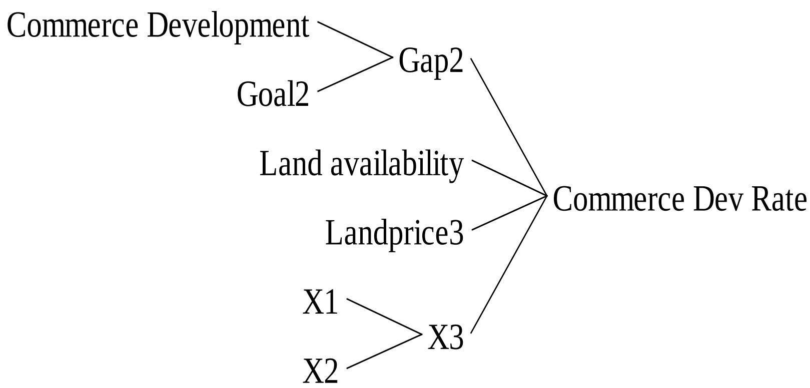

Figure 10: Commerce development rate related factors

6.3 City Development

City development is a part of city managers' duty making sure that with the population growth, the facilities are also constructed on time with sufficient land allocated to that purpose. Some factors have impacted this decision and they are as presented in Figure 11 below. The city development rate is the function of land availability, land price, and extent of the expansion that the city had in the past.

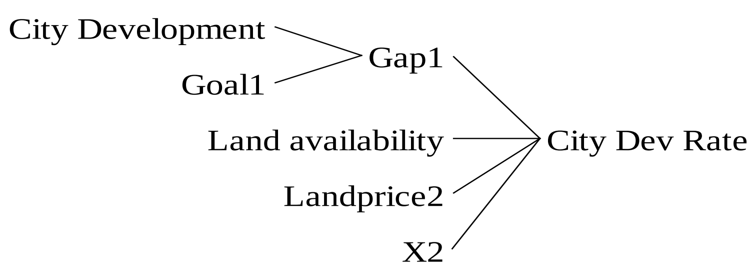

Figure 11: city development rate related factors

6.4 People Satisfaction

Due to the fact that land allocation to housing and business locations is hand in hand with the new jobs for the people living in the same part of the region, it would bring extra satisfaction for the people in the area. As a result of that, higher income is for the people involved and then the enhanced life quality. Figure 12 showing a structure depicting that satisfaction rate is a function of life quality, people welfare, construction growth, investment growth, welfare factor, and life quality factor. Variables impacting dissatisfaction rate shown by Figure 13 and a trend of people satisfaction over 120 periods is shown by Figure 14.

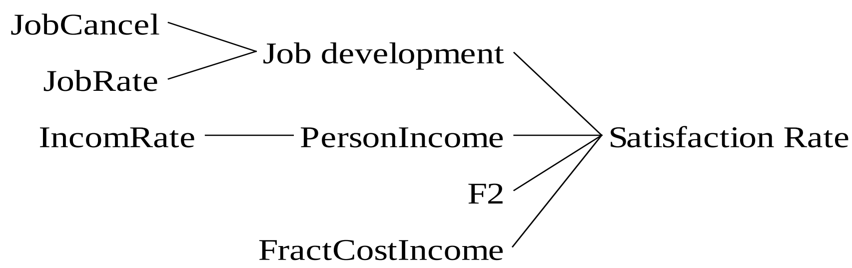

Figure 12: people satisfaction related factors

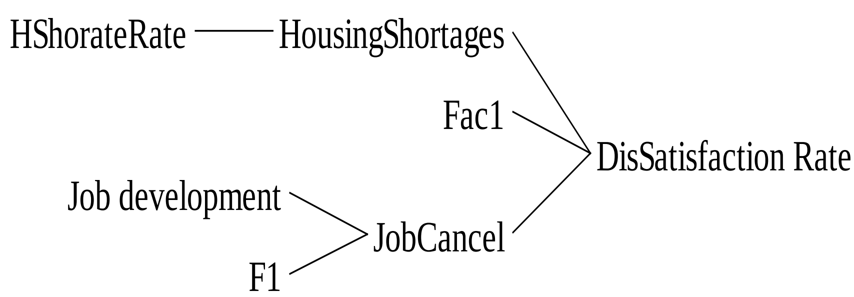

Figure 13: people dissatisfaction related factors

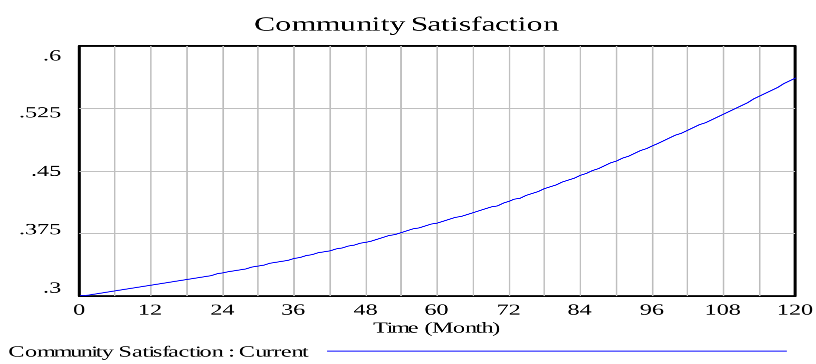

Figure 14: a trend of people satisfaction over 120 periods

6.5 Personnel Income

Income plays a significant role in people's life. Income rate is a function of some factors as are depicted by the Figure 15 shown below. The formula used below allows us to generate income rate and Income of the people. Figure 16 demonstrates the trend of total income over 120 periods.

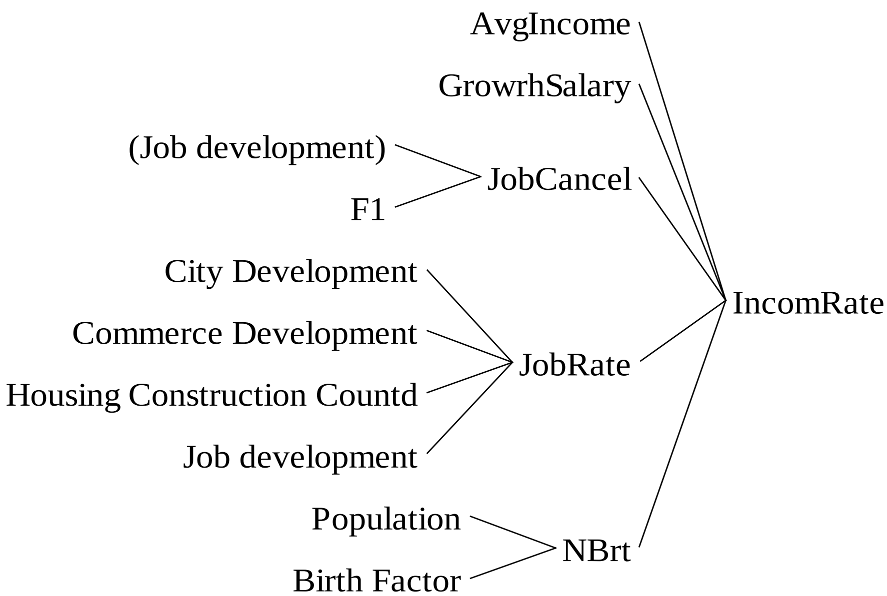

Figure 15: Income rate related factors

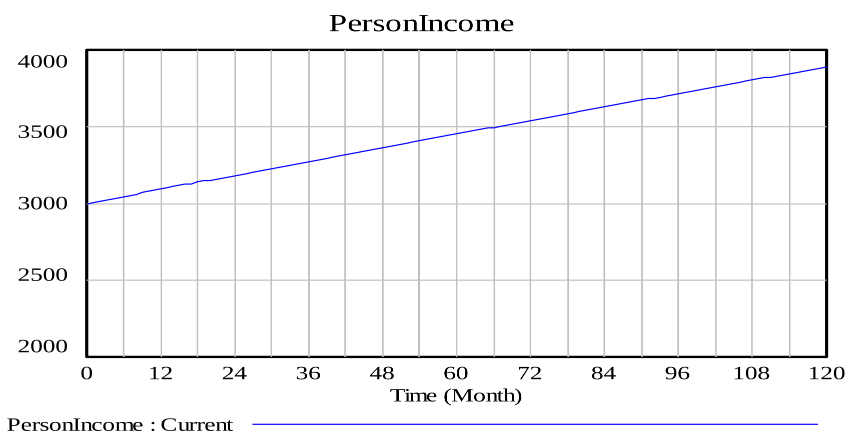

Figure 16: the total income over 120 periods

6.6 Life Quality

Life quality is an index that is given high value by the community people. In addition of having satisfied people in a community, people's life quality is a factor for staying in the community. Life quality is a function of various factors as are shown by the structure presented by Figure 17.

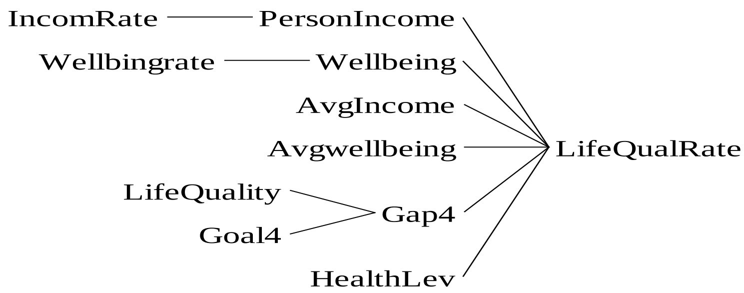

Figure 17: life quality rate related factors

Figure 18 shows that life quality under the current policy implemented by city managers for land planning is on the rise and it is merging to a level of 0.78 which is a highly acceptable number.

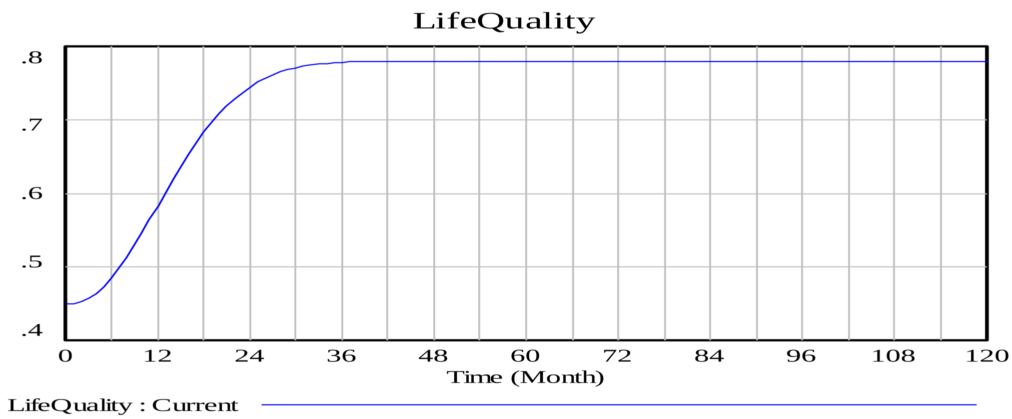

Figure 18: Life quality trend over 120 periods

6.7 People Wellbeing

People's well-being is a function of various factors as it is shown by the following structure through Figure 19. A formula presenting well-being rate is provided as was shown in the Vensim's software.

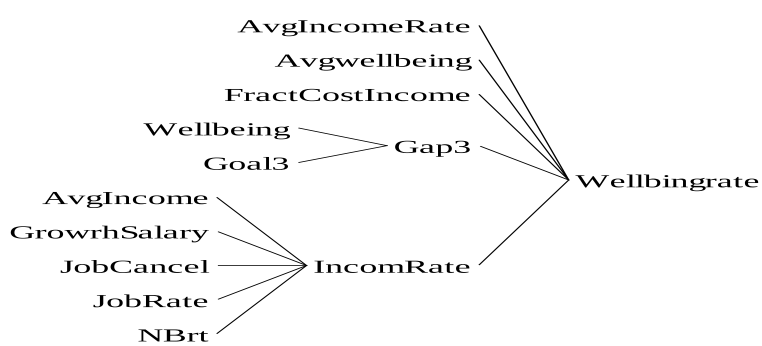

Figure 19: well-being rate related factors

Figure 20 shows that people's well-being under the current policy implemented by the city managers for land planning is on the rise and it is merging to a level of 0.75 which is an acceptable number.

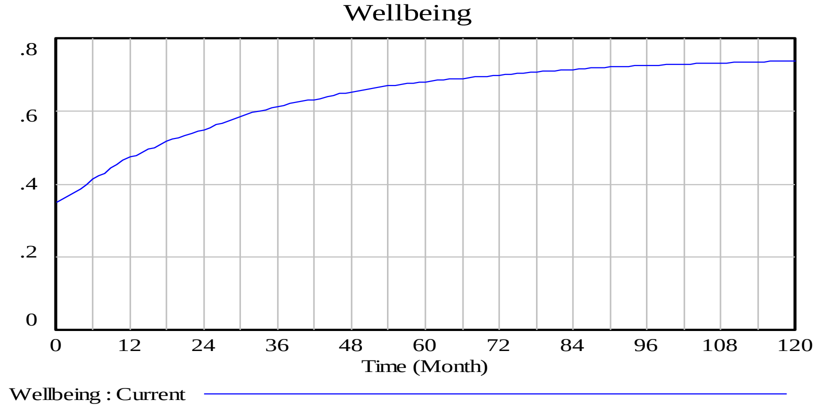

Figure 20: people well-being over 120 periods

6.8 Job Development

New job development and its availability are highly important for people living in a community. People who have job and work satisfactorily would be beneficial to his/her family, community, organization and growth of the city. Therefore, commerce development and job development are somehow related to each other. Although, we know that new job development requires capital, new idea and innovation. Figure 21 shows job development trend over 120 periods.

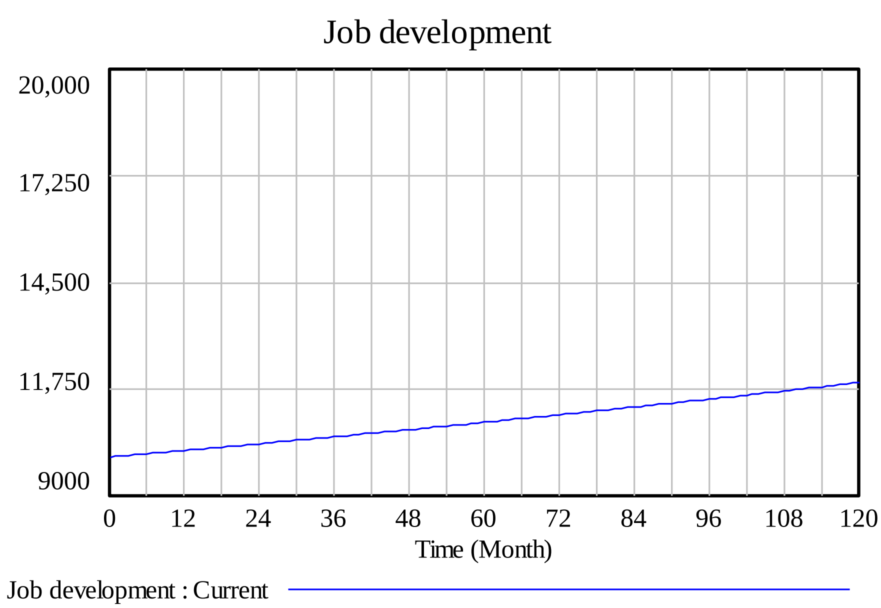

Figure 21: Job development trend over 120 periods

7. Indices evaluations

Table 5 shows numerical values of fractions of housing counts to people, housing shortage to housing counts and housing shortage to population, for each 12 months (year). More information obtains from Figure 22, 23, and 24 showing the trends for selected variables.

Table 5: numerical presentation of three indices by 12 Months periods

Periods	Housing Counts/Pop	Housing Shortage/Housing counts	Housing Shortage/Pop
0	0.2000	0.0050	0.0010
12	0.2001	0.0338	0.0068
24	0.2020	0.0613	0.0124
36	0.2043	0.0861	0.0176
48	0.2080	0.1074	0.0223
60	0.2117	0.1255	0.0266
72	0.2156	0.1397	0.0301
84	0.2203	0.1509	0.0332
96	0.2262	0.1577	0.0357
108	0.2293	0.1625	0.0373
120	0.2341	0.1644	0.0385

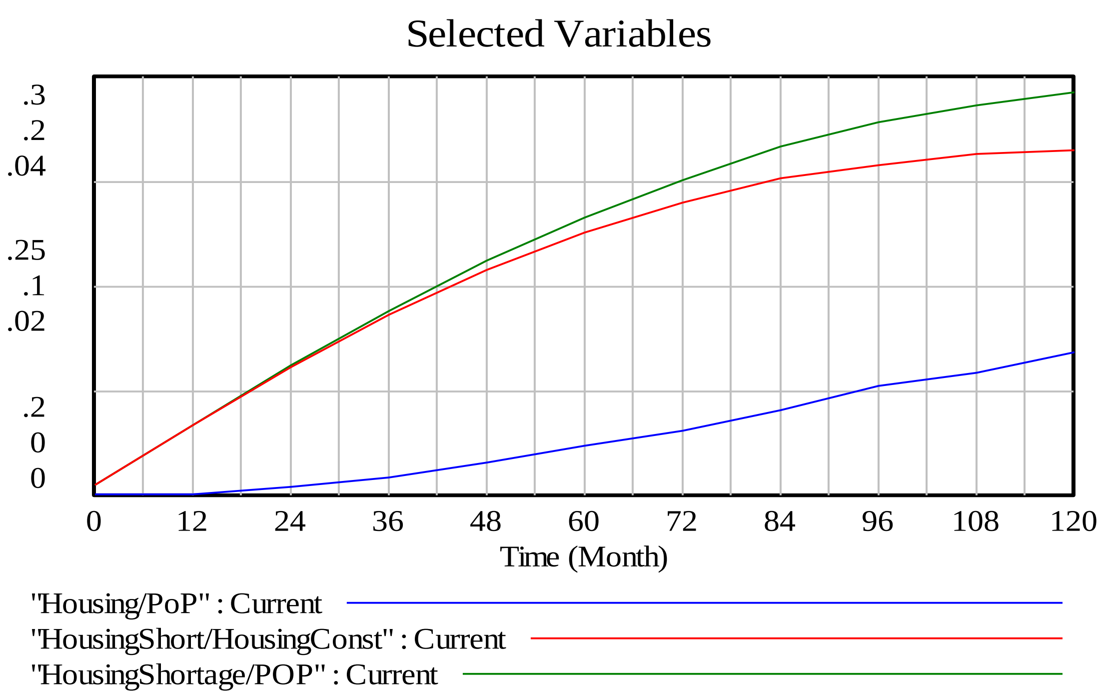

Figure 22: comparing the trends of ratios of selected variables

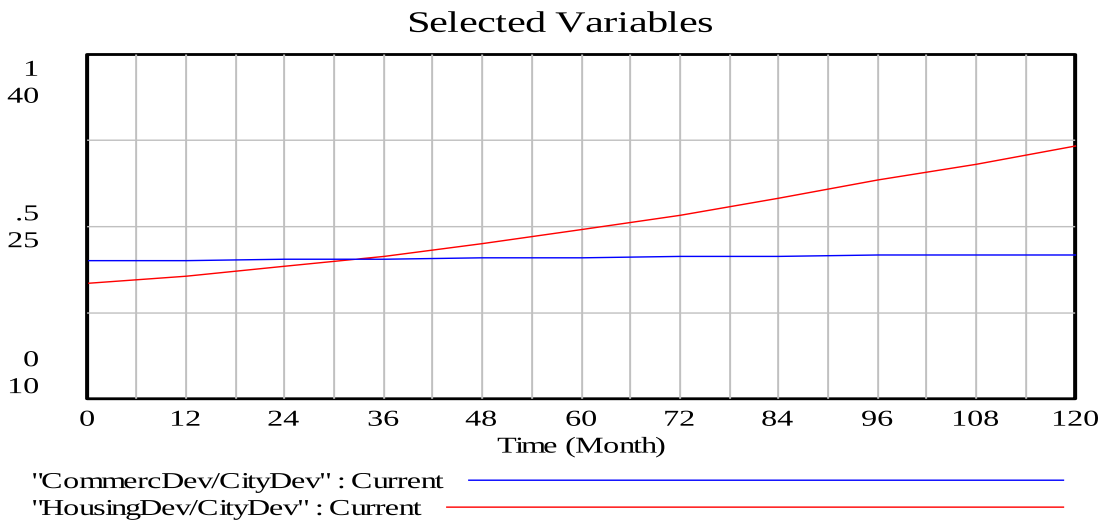

Figure 23: comparing the trends of ratios of selected variables

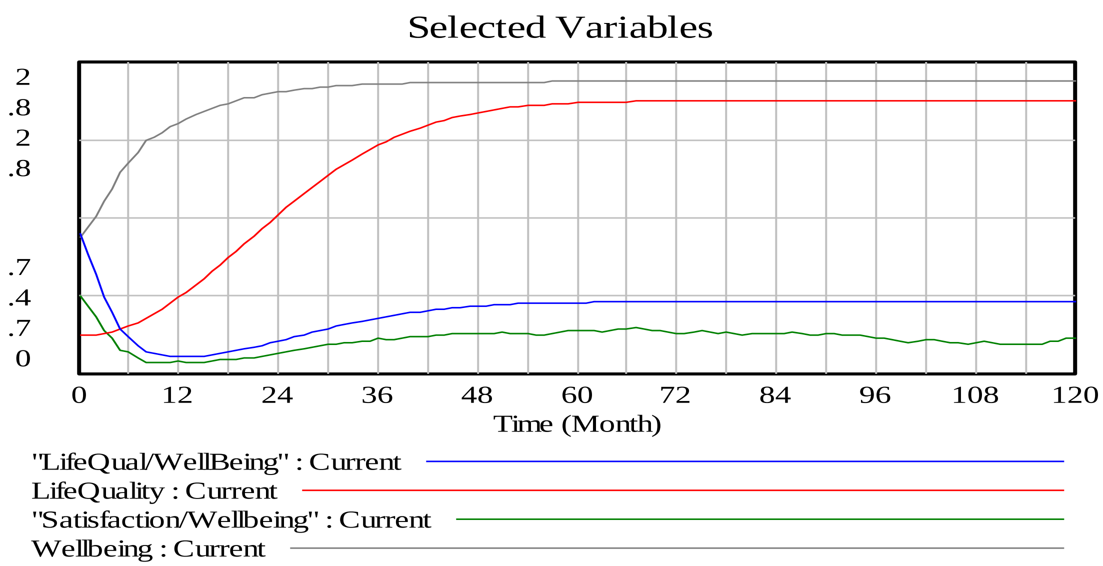

Figure 24: Comparing the trends of rations of selected variables

8. Model Assessment

Once a model is simulated and its results are considered to be acceptable for the purpose under investigation then verification and validation of the model is in demand. The following sections discuss this phenomenon regarding the proposed model.

8.1 Model Verification

Some simulation software has the capability of model verification. In system dynamics, verification is comprised of (1) units check, (2) formula check, and (3) structure check. Vensim PLE software checks for units used in the mathematical model building of the problem built by the analyst into the software. When units do not match the simulation collapses and specific errors are generated by software. Formula check, although very important to simulation output, does not get checked by the software. This is a part of the analyst task. In this regard, analysts should check for the soundness of the results obtained and type of trend expected beforehand. Structure check is interpreted in two ways. One interpretation is that unit check and formula check together to make the structure check. Other researchers say that structure check is related to that structure generated by the cause and effects diagram through mental modeling. Once all formulas and unit checks are completed, then the model is simulated.

8.2 Model Validation

Model validation by Vensim PLE is possible. This is done by the “reality check” option built into the system and can be used by the researchers. Unit's validation is also a part of the Vensim PLE software helping researchers to validate the mathematical modeling done in the system. There are more than 35 tests that can be used for model validation. It is not customary to use that many tests for this purpose. Usually tests such as structure verification tests, dimensional compatibility tests, behavior reproduction tests, and border sufficient tests. Giannanasi et al. [30] conducted a study on enhancing confidence in simulations [30].

8.2.1 Model Credibility

Credibility or operational validation is defined as determining whether the behavior of the model output has sufficient accuracy for the model’s intended purpose over the domain of the model’s intended applicability [70], [68, 69], and [45].

8.2.2 Border sufficient test

With this test, we determine the level of holism of the model up to the level of the problem under study. Is the model's level appropriate and encompasses all relevant structures, including the variables and effects of feedback needed to address the problem? Does this structure, with such a boundary, fit the purpose of the study? According to the purpose pursued in this study, endogenous variables have been taken into account and enough exogenous variables have been applied. So, this test is valid. For example, when there is a suitable condition to increase people's income, does life quality increase to a higher level, taking all other conditions fixed?

8.2.3 Structure verification test

With this test, we can check the suitability of the model to its goals and the problem it addresses. This means that how much model structure is consistent with the existing knowledge of actual system structure. Also, with this test, we want to see whether the most relevant real system’s structure is modeled. Three steps were taken to make this test’s confirmation possible. First, the necessary investigation was made in relevant literature to find out all possible related factors for such an integrated problem. Second, structures proposed by other authors for close problems were studied. Third, consultation with experts on the model building based on the presented mental diagram was made. At last, experts confirmed the model structure, and hence the test was verified.

8.2.4. Dimensional compatibility test

With this test, we determine whether the dimensions of the variables in all equations on both sides of the equations are in equilibrium. This test was performed according to Vensim software and it was found that there was no discrepancy between dimensions of variables in any of the mathematical equations used.

8.2.5 Behavior reproducing test

System dynamics models are primarily used for policy analysis to ultimately lead to improved policy-making in the organization [70]. After obtaining a valid system dynamics model that has passed various validation tests and a behavioral understanding of the current policy structure is assessed the model can be used for designing alternative policies [70]. For this purpose, in this study, three scenarios are discussed, which are discussed below. Figure 2 shows the behavior reproductive test for community satisfaction.

Table 6: real and simulated values of people's satisfaction

Years	Satisfaction Level	Satisfaction Level Simulation	Ratio of real to simulation
2010	0.36	0.3600	1
2011	0.37	0.3610	1.025
2012	0.38	0.3640	1.044
2013	0.38	0.3699	1.027
2014	0.40	0.3787	1.056
2015	0.41	0.3913	1.048
2016	0.42	0.4070	1.024
2017	0.43	0.4278	1.005
2018	0.43	0.4516	0.952
2019	0.43	0.4797	0.896

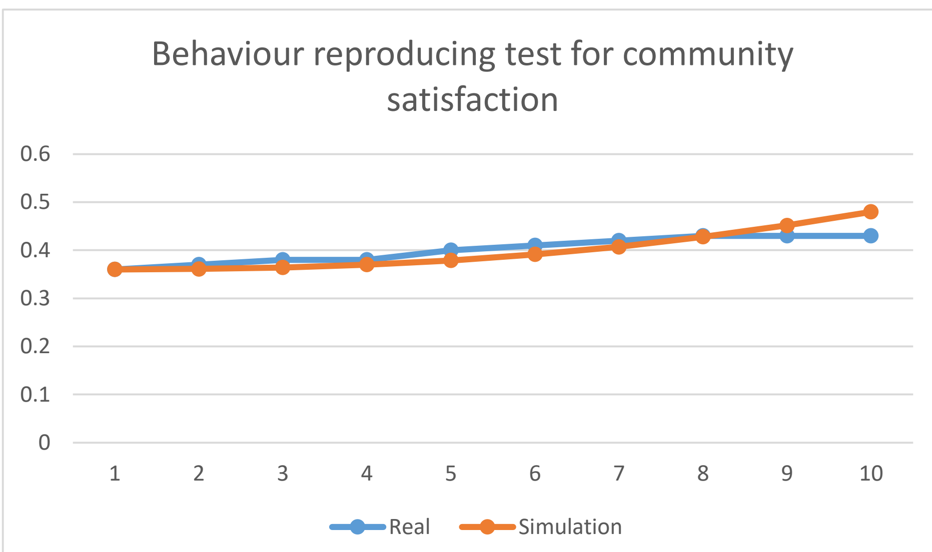

Figure 25: behavior reproductive test for community satisfaction

With this test, we want to show how much the model's output is consistent with the system's real performance. The case used here is a small city with very low people's satisfaction level due to not being by the Silk Road and not having a national road passing through that. This community was very unsatisfied with the states' policy-making and local decision-makers, however. Hence the level of satisfaction was set to 15% for a long time as history shows.

Since road construction for this community, just for the purpose that this community was demanding, was both very costly for the state and not economically sound community expansion and land planning were considered to be an alternative. Taking this strategy into consideration can have significant impacts on the city expansion, land value, and community income level and welfare. The satisfaction trend shows growth and at the same time, the income level and welfare of the community is increasing to a higher level than expected.

9. Scenarios Development

Three scenarios are considered for this case and they are as defined below with X values showing the percentage of land allocating to each situation. In all cases the sum of Xi are equal to 1.

Base Scenario Data

All computer simulation results presented above are for the base scenario with:
In this scenario, we have:
Housing =X1=0.40
City development=X2=0.40
Commerce=X3=0.20

Scenario 1 Data

In this scenario, we have:
Housing =X1=0.55
City development=X2=0.35
Commerce=X3=0.10

Scenario 2 Data

In this scenario, we have:
Housing =X1=0.55
City development=X2=0.10
Commerce=X3=0.35

Figure 26 compares the index of Index1 = HousingShortage / POP taking these three scenarios into consideration. The best scenario is 2 which generate the lowest value of Index1.

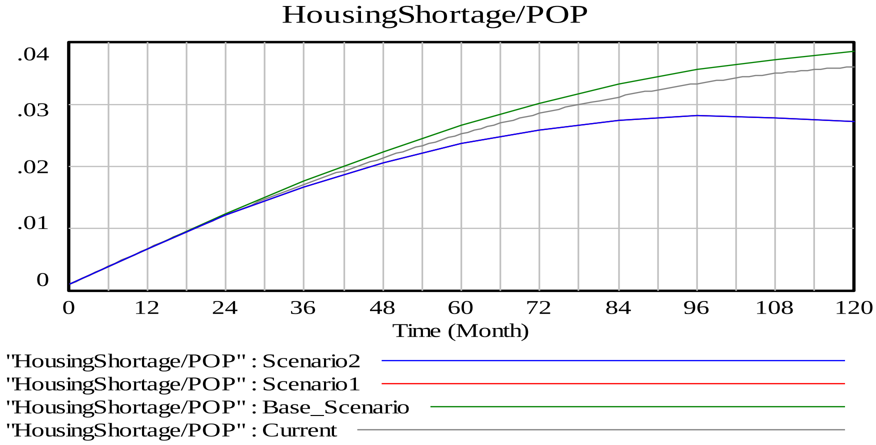

Figure 26: trend of fraction of housing shortage to population (index 1)

Figure 27 compares the index of Index2 = Housing / POP taking these three scenarios into consideration. The best scenario is 2 which generate the highest value of Index2.

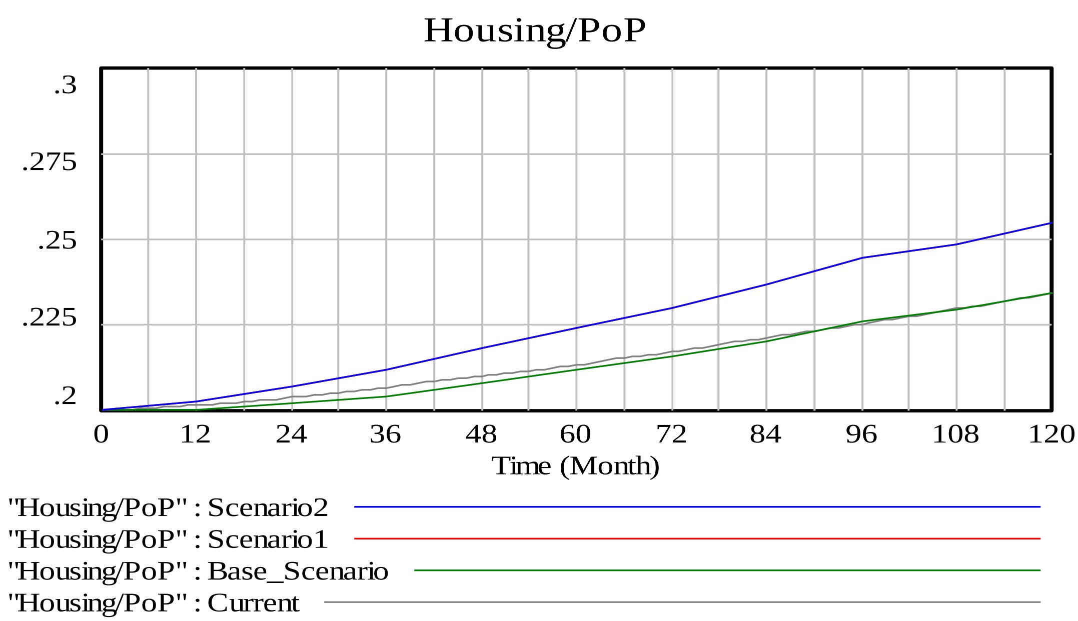

Figure 27: trend of fraction of housing counts to population (index 2)

Figure 28 compares the index of Index3 = HousingShortage / HousingConst taking these three scenarios into consideration. The best scenario is 2 which generate the lowest value of Index3.

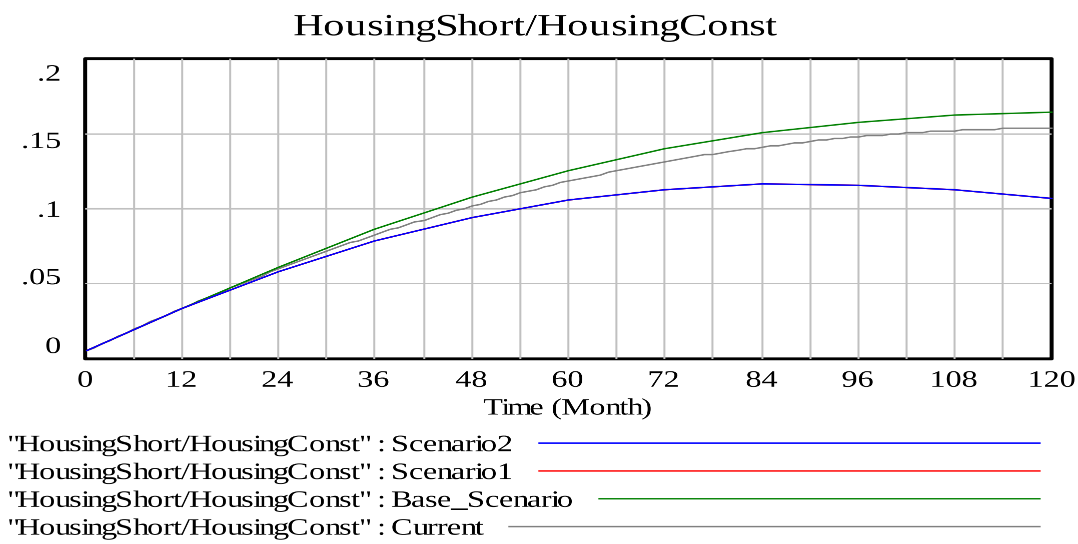

Figure 28: trend of fraction of housing shortage to housing counts (index 3)

Figure 29 compares the Index4 = Commerce development /City development and Index5 = Housing development / City development taking these three scenarios into consideration. The best scenario is 2 which generate the highest value for Indices 4 and 5, respectively.

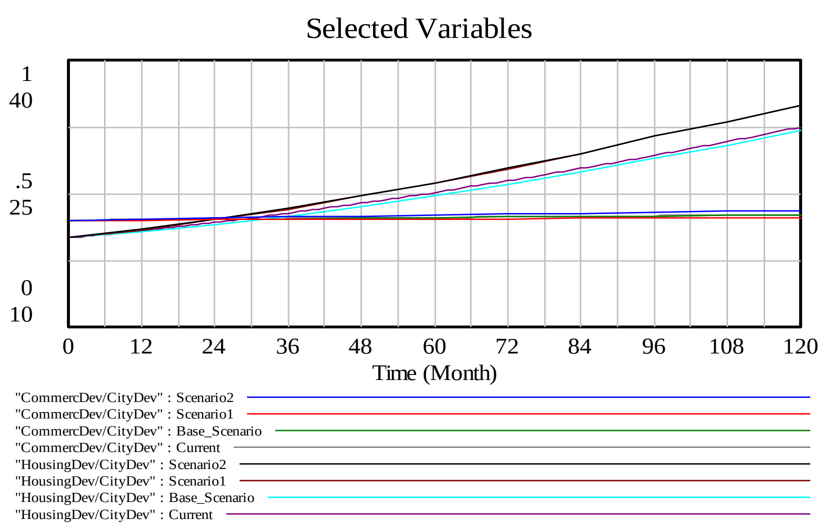

Figure 29: comparison of indices 4 and 5 using three scenarios

Figure 30 compares the index6, index 7 and index 8 as are defined below:

Index 6 = Community satisfaction is related to scenario 2 as shown by Figure 30
Index 7 = Life quality is related to scenario 2
Index 8 = well-being is related to scenario 2.

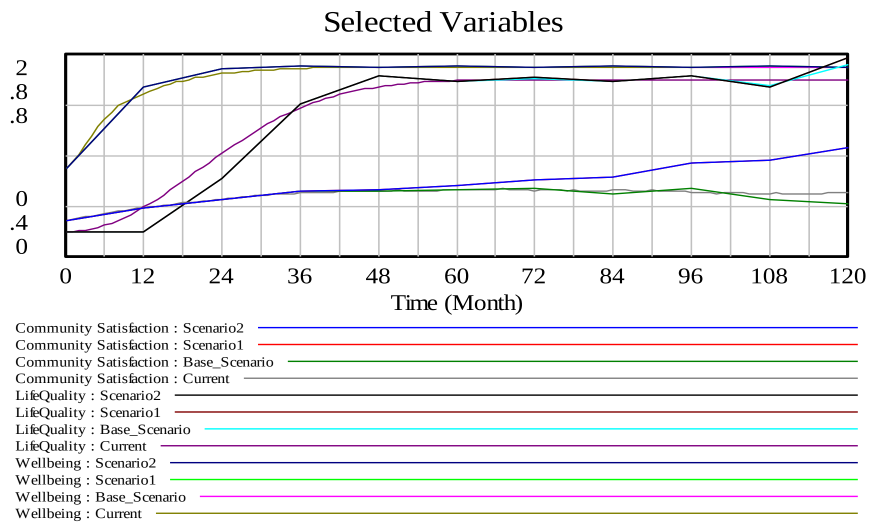

Figure 30: comparison of indices 6, 7, and 8 using three scenarios

Our analysis of these three scenarios indicates that scenario 2 is the best one and can be employed by the city planners to set policies.

10. Managerial Insight

To determine the behavior of people's satisfaction concerning new land allocated to housing, site development as well as city development, business development, cultural development, and recreational purposes, this model can be used as a handy tool. Additionally, it is possible to determine the quality of life and income of residents and the population trend over time as the model proposes. The extracted managerial insights of this study for managers and decision-makers are brought as follows:

1. Knowing that trends of housing counts and commerce development using computer simulation are possible then policymakers can study them right before considering urban land allocation and its implementation.

2. Studying the trends of community satisfaction and people's well-being is possible using computer simulation program.

3. Life quality and job developing trends as a result of urban land development is also possible through the execution of proposed computer simulation program by this author.

4. By using proposed computer simulation program policy makers can simultaneously study the trends on: city development, housing counts, commerce development, people's satisfaction, personnel income generation, life quality, people's wellbeing, and job generation.

11. Implications

In this section, theoretical contributions, policy contributions, and software contribution are discussed.

11.1. Theoretical contributions

From the theoretical perspective, this paper contains several theoretical contributions. First, a new look at the urban land allocation and how it can be used for managing people's need and expectations. Such an understanding of people's trends of expectations gives city engineers, practitioners, policy makers, researchers and academics a precise view and extension of the problems dealing with and how should deal with. Second, this paper is the first to study interrelationships among urban land allocation and people expectancy and beliefs. Third, we know that system dynamics is based upon the global and holistic vision hence it is used for solving specific problems and analyzing complex systems. This article has shown that this approach is suitable for studying dynamic indices performance and their management. Fourth, previous studies have neglected several benefits of dynamics performance trending of people's expectations such as well-being and satisfaction when a new land allocation in the urban area is allocated. System dynamics is a felicitous tool for researchers and scholars to investigate the interrelationships among various factors. Fifth, a new technology in the form of a new system dynamics computer model ready for simulation is provided that plays as an aid to city developers and policymakers. Lastly, we asked experts from the industry to provide data, which required a proper manner to deal with the ambiguity of input data.

11.2 Computer software contribution

Urban land allocation is essential in the sense that it ponders both city land management and the community's economic growth in the long run. The use of a newly developed software or computer simulation program for land allocation and development is a must providing that it can measure all necessary indices that are important to both parties of city engineers and community. City managers and policy makers should have an eye on the following portfolio optimization type problem: Max {Returns on land allocation | provided that: land availability for allocation hold; benefit and income generation satisfies; and environmental constraints hold}. Here, the computer simulation program under study is a new technology, and its usage in most urban land developments, in large number of cities all around the world, is on the verge of origination. This paper aims at analyzing the interrelationships among the urban land allocation factors and community expectations and related factors. So, the outcome of this study acts as a comprehensive guideline for managers in urban land development as well as city expansion and new city development.

11.3 Policy contributions

Based upon the scenarios proposed in this study, our findings strongly support the fact that popolicymakerslicy makers can play a key role in providing a proper setting for community expectations with better urban land development management. Generally speaking, managing a situation right before a final decision, using computer simulation, is highly effective and professional. Organizations using such computer simulation to generate all sorts of key trends can implement better policies and hence generate better results in the long run. Due to rapidly rising living expenses and shortage of jobs in a community, as a result of population growth and immigration, policymakers should be more sensitive to the needs of community and hence the importance of effective and on-time decisions is highly demanding. This article with its simulation computer program provides an opportunity for city engineers and policy makers to use that for effective decision making.

12. Conclusion

The study of community' satisfaction is of high concern to city developers for measuring how well they are doing their duties as well as how well people are seeing their city grow with respect to their advantages and values. City managers and policy makers have hands on many issues such as land allocation for different purposes. To do land planning, demands for land reservations due to environmental uses, economical, ecological, social, and cultural cases must be realized. Analyst employed different approaches to find the trends that goal variables are showing by the passage of time. SD is known as a good tool for this purpose as it is used in many different types of problem solving. Vensim simulation software was used to simulate the model of the problem as shown by figure 6. The results of simulation are shown by Figures 12 through 16. As the trend of residents' satisfaction shows, it is possible to improve the satisfaction level over time to a level about 90% from about 10% over 100 periods. Meanwhile, the level of residents' income due to land planning in the area is up from 5000 to 5260 in the same periods as satisfaction level has been studied.

Due to the fact that limited studies appeared in the literature on land allocation and planning with its impacts on residential satisfaction, wellbeing, and quality of life, this research can play a big role in originating other studies in this area. Although, some communities are paying attentions to the needs of their residents and businesses, others are doing recklessly. Hence, a lot of city managers and land developers are in need of having a practical tool helping them in measuring peoples' satisfaction. Taking all discussion from above sections into consideration, now this author can propose following research areas as far as small community' satisfaction is concerned (1) how land allocation can have impacts on the land price that are used for housing construction in the region? (2) Research can be conducted using a new structural framework for the proposed problem different from the one proposed in this article. Researchers may not always have hands on real data. However, without real data, researchers cannot determine meaningful behaviours for goal variables and hence management cannot make valuable decisions using that. To deal with such problems, researchers have to use some data that are either close to the reality or some data that might be randomly generated for that purpose. The latter happens more often in studies, due to the lack of support by relative organization or data inaccuracy.

Knowing that a community with its related factors is a complex system, therefore the use of factors affecting the actual system will make modeling of the problem very complicate. So, in the present study, factors such as road construction, sewage planning, water reservoirs, utility centers, transportation hubs, pollution problem, inflation rate, and community size are discarded. These excluded variables are good candidates for model expansion and sophistication. Since this study did not deal with cultural problem of the community, a study can be conducted taking this dimension into consideration for generalization purposes as well.

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