Chapter 2

Current Approaches to Locate Urban Public Services

2.1 Introduction

The chapter 1 provided an introduction to the location of urban public services and the importance of effectively and efficiently locating public services in a dynamic urban city environment. This chapter presents the current approaches to locate urban public services that have been identified during the literature survey. During this chapter, the author will compare the positive and negative points of each of the approaches. After the comparison, the author will be able to identify the problem that need to be addressed from this research.

2.2 Agent based approaches

Urban shrinkage: a vicious circle for residents and infrastructure [21] presents the use of multi agent technology to solve the problem of under-utilization of houses in urban regions of Europe. Through this research, Schwarz and her colleagues have identified that there is a relationship between residential location and infrastructure facilities in utilizing houses by the people in the city. Therefore, they have used two types of agent models as resident agents and infrastructure agents in implementing their solution. The resident agents locate different households based on urban structure and infrastructural facilities provided while infrastructure agent changes the infrastructure facilities based on the residential choice. For this reason, the decision of one agent depends on the decisions of the other agent and vice versa. The researchers have identified the circumstances with which the whole city becomes underutilized as well as the situations that may only underutilize a specific area in the city.

Rebuilding New Orleans: An Agent-Based Modeling Approach [1] investigates the use of multi agent technology in rebuilding the urban structure of the city, New Orleans. Through this paper, Aamir and his colleagues have focused on implementing an agent based model which considers the influence from a natural disaster such as the hurricane Katrina, to the urban structure of the city. Also, the urban planning policies of the government were also considered during the rebuilding process of the city. So, they have implemented some resident agents to build the houses of the city while maintaining the relationship between the possibilities of disasters such as Katrina and the government urban planning policies.

Agent-Based Modeling of Residential Distribution [4] presents a multi-agent approach that implements the dynamics of the urban residential distribution by considering the aspects of demography and social science. Through this research, Benenson and his colleagues have discussed the relationship of population distribution with the urban residential distribution by using some abstract agent type models with the use of the probabilities of population in different regions.

New Tools for Simulating Housing Choices [23] illustrates a platform to model hybrid urban structures based on geography of the city. The researchers have identified geographical simulation as one of the entities that need to interact with urban land use and transportation of the city. They have designed a hybrid model encompassing cellular automata and agent based methodologies to explain the complex interactions between the geography, urban land use and transportation and implemented a prototype of residential location model to present how the concepts of hybrid model can be used to make housing choices throughout the city.

An agent based model for Urban Structure: The case of Belo Horizonte – Brazil [11] presents how a group of agents can be used to model the urban structure considering the spatial variations of urban areas and infrastructure facilities. The author of this paper had used an already developed cellular automata model [25], which used land use, income and neighborhood as the theoretical basis to develop his research. The above said model had been extended by including urban land prices as a key factor to decide the land uses of the model.

The Developer's Decision Calculus: An Agent-Based Model of Commercial Development [10] presented an agent based model which facilitates the commercial development in urban cities through the interactions between the investors and the governments of those cities. According to this paper, when developing cities, the developers are more biased on making profits from the development projects and they did so through time delays. The local governments of the cities had expected a considerable amount of economical development through the commercial development projects and they were more concerned on land use regulations which increase the amount of tax revenue. For this reason, this paper highlights the necessity of using agents to make dynamic interactions between the commercial developers and the cities.

Agent-based approach to modeling environmental and urban systems within GIS [16] introduced a real time computational environment for researchers to make experiments on the complex behaviors of environmental and urban design models with respect to changes in time and space. This approach had been developed using Distributed Artificial Intelligence (DAI) to provide the capability of switch between real time environment and the artificial world for researchers to have a dynamic observer point of view. However, this agent-based approach used only reactive agents for their environment and urban system models by limiting its capacity to integrate within GIS.

ARTHUR: A Collaborative Augmented Environment for Architectural Design and Urban Planning [8] was a collaborative approach for complex and real time architectural design and urban planning. This technology had the capabilities in tracking, collaborating and visualizing natural 3D environments as virtual objects. Therefore, architectural design and urban planning could be both individually and in group. Also, the traditional CAD based 3D visualization approach was integrated in this ARTHUR environment, thereby, providing the ability to make additional sketching and extrusions to the architectural design. However, this approach needed a lot of preparation and set-up time to track the system into the user interface using the ARTHUR framework and GRAIL system. Also, experts could simulate the environment only for solar heat level changes and wind condition changes.

Management of Recreational Areas: GIS, Autonomous Agents and Virtual Reality [7] simulated the contribution of land usage patterns, urban land modeling, and virtual reality for the popularity of tourist destinations of various land models. To implement this approach, visitors had been modeled as rule based agents and their behaviour to select the next location to visit were determined by predefined rules. People who manage the environment could make decisions by obtaining visitor satisfaction levels and environmental impact levels as the output from this approach. However, this approach needed to be developed further to make the urban environment more challengeable.

Ontology Driven Concept Modeler for Urban Development [20] was an ontology driven approach to integrate the capabilities of conventional urban design softwares through reducing their individual complexities. Ontologies that were built inside the concept modeler could be extended by inserting new rules to assess many urban designs. This approach had the capabilities to overcome issues such as inability to access expertise knowledge and lack of resources to utilize urban models. However, in this approach,

sometimes there were conflicts occured between classes due to performing multiple functionalities. Also, a lot of memory was consumed by the software while converting large GIS data sets in to instances of an ontology. Finally, they had pointed out the importance of integrating this approach to handle other consumption.

UrbanSim: Modeling Urban Development for Land Use, Transportation and Environmental Planning [24] introduced an emergent urban planning model for maintaining land use, transportation and environmental quality. This approach extracts input choices from households, businesses, developers, and governments to implement interactions between them in a real state environment. The agents in this system represent the behaviours of each of these users. Therefore, the functionalities of each agent can be clearly understood in terms of the changes in the environment. This paper highlights the importance of extending this approach further to make it more robust and accessible while integrating developments of other urban planning methods as well.

2.3 Cellular Automata and Vector based approaches

Irregular vector-agent based simulation for land-use modeling [13] approach uses discrete irregular objects to represent land entities with a multi-agent framework. Also, the concepts behind von Thunen's theory of agricultural land use are being used during the verification process of urban city models. This approach has the potential to simulate dynamically changing real world urban environment in the computer as well as implementing the computer generated urban model in real world environment. Also, it has the capacity to simulate the actual geometric boundaries of the urban environment by assigning vectors to represent individual object locations. Therefore, this approach has the capability to represent real world objects such as buildings, roads and trees as natural as in the real world environment. Objects' behaviour may control dynamically because the objects are hierarchically structured. However, this approach has been verified using only the theory based knowledge. For-this-reason, this approach has to be verified further using real time data to generate generic hypothesis models that are accurate and flexible as real time urban planning models.

Modeling Urban Growth Dynamics using Cellular Automata and GIS [2] presents an urban planning mechanism while handling the complexities of the city environment such as urban dynamics, emergence and self organization. The proposed mechanism was applied to the

city environment of Riyadh, Saudi Arabia to simulate the complexities while the city grows. The theoretical basis for this approach is a fuzzy cellular automata model that can predict the future trends of urban development in the city.

Sensitivity Analysis of a GIS-based Cellular Automata model [17] presents a GIS based cellular automata growth model to identify the uncertainties that can happen as a result of the errors of the real time data models or due to changes in the model parameters such as the neighborhood size and type. These parameters changes are analyzed through the process of sensitivity analysis of the cellular automata model. The outcome from the model may illustrate the behavior of the cellular automata model in a situation of uncertainty.

Analysis of the Stochastic Component of Urban Models Based on Cellular Automata [12] presents how the sensitiveness of the urban models can be differentiated by applying some randomness to the cellular automata model. According to the author of this paper, cellular automata models are capable of regenerating urban dynamics and can be used to analyze the trends in urban growth. In this research, a sample cellular automata model was used to compare the urban growth in situations where different type of randomness were applied on the city models using different methods of generating randomness.

Cellular automata and GIS based land use suitability simulation for irrigated agriculture [26] describes the use of cellular automata urban models to evaluate land use suitability in the area of agriculture. In this research, multi-criteria evaluation methodology [3] was used to analyze different environment conditions in the desk study area. These environment conditions were collectively represented as a layer which considered as the most initial conditions of the cellular automata model to generate the agriculture land use models. Then, these conditions were weighted using analytical hierarchy procedure approach [9] and a temporary baseline suitability layer was generated. The conditions of temporary baseline suitability layer are the input conditions to generate the next cellular automata model for the agriculture land use simulation. The generation of new temporary baseline suitability layer is done iteratively and it is based on the previously generated temporary baseline suitability layer. The final suitability layer is generated using cellular automata spatial simulation. The final suitability layer will be simulated inside a GIS framework and generate the land suitability map. This map will show the land use blocks in the desk study area that are suitable for agriculture purposes.

Using Cellular Automata to generate high-density building form [14] investigates the use of cellular automata technology to plan high-density buildings in Asian cities. The author of this research has selected cellular automata as the technology because of the flexibility, speed and low cost to plan the city. This paper highlights the possibility of using the features of classical cellular automata techniques such as uniform volumetric high-resolution models and globally consistent rule execution to renew the existing architectural city models.

2.4 Stochastic simulation techniques

Facility Location: A Review of Context, free and EMS Models [19] presents an approach to locating public services by considering the situation of the environment and characteristics of the service. This paper illustrates the use of this concept to locate fire trucks in different locations of the city. When locating these services, the model considers the possibilities of service requirement and capability of comparing several locations and chooses a suitable location. This increases the potentiality of locating the service in complex situations in the city environment.

A Simulation Model of Land-Use Change in the Lake Tahoe Basin of California and Nevada, as Used in a Decision-Support System [15] describes how a stochastic land use model can be used to plan the development and retirement of individual land lots around the basins of the Lake Tahoe of the city of California. This model considers the environmental (clarity and health) and socioeconomic (affordable housing) characteristics of the land area as well as the government environmental regulations, development activities in and around the river basin and forestry conservation practices. The urban land use model outputs the possible land slots changes and the land slots changes that is going to happen in future. The uncertainties and variation of land slots are extracted by considering the development or retirement of land slots as active individual operations and running the model with multiple iterations to accumulate cumulative statistics of those operations. These statistics are inputted to the basin wide model and output from the basin wide model is inputted to lake clarity model. Therefore, at the end, user will be able to take decisions on land use changes in the critical environment, both, quality wise and clarity wise.

2.5 Virtual Reality and 3D Modeling approaches

3-Dimensional Virtual Reality in Urban Management [6] provides a flexible 3D environment to build virtual cities and to manage the previously planned virtual cities. This technique provides the user with some urban managers who can simulate the interactions between different objects in the 3D environment and manage the location of the objects in the urban city environment. The urban managers have the capability to extract the physical and social data from the environment that are needed for the simulation. In addition, these managers have the necessary tools to analyse this data to make decisions regarding the urban environment.

Hybrid Decision Support System for 3D City Planning [22] uses both desktop based environments and semi-immersive virtual reality systems (VR) to provide a city design process workflow that is similar to real world city planning. This approach has the capacity to overcome the interaction issues in existing virtual reality based approaches by allowing the software to run both in virtual reality systems (VR) and desktop based environments. The desktop based environment provides the ability to edit digital geographical objects while VR systems handle the interactions between different objects and finally develop the city plans. However, Hybrid Decision Support System doesn't show a significant increase in performance relative to other approaches while always require a human to control the system.

2.6 Comparison of current approaches

Some of the current agent based approaches to locate urban public services are Urban shrinkage: a vicious circle for residents and infrastructure [21], Rebuilding New Orleans: An Agent-Based Modeling Approach[1], Agent-Based Modeling of Residential Distribution [4], New Tools for Simulating Housing Choices [23], An agent based model for Urban Structure: The case of Belo Horizonte – Brazil[11], The Developer's Decision Calculus: An Agent-Based Model of Commercial Development[10], Agent-based approach to modeling environmental and urban systems within GIS[16], ARTHUR: A Collaborative Augmented Environment for Architectural Design and Urban Planning[8], Management of Recreational Areas: GIS, Autonomous Agents and Virtual Reality[7], Ontology Driven Concept Modeller for Urban Development [20] and UrbanSim: Modeling Urban Development for Land Use, Transportation and Environmental Planning [24]. Most of these agent based approaches [16] use reactive agents to respond to the situations in the city

after situations occurred. The most essential requirement of the agents when locating public services in a dynamic environment is to act as proactive to minimize the collisions between different services in the environment. Some of the agent based approaches [23] uses agents only to simulate the environment and all the decisions regarding locating public services are taken by the humans. Therefore, service agents will not get a chance to take decisions by their own.

The author has compared Irregular vector-agent based simulation for land-use modeling[13], Modeling Urban Growth Dynamics using Cellular Automata and GIS[2], Sensitivity Analysis of a GIS-based Cellular Automata model [17], Analysis of the Stochastic Component of Urban Models Based on Cellular Automata [12], Cellular automata and GIS based land use suitability simulation for irrigated agriculture [26] and Using Cellular Automata to generate high-density building form[14] as the current cellular automata approaches that are available to locate urban public services. The main issue in all these approaches is that the cellular automata techniques are mostly suitable to simulate the suitable locations to locate the public service after the data is fed by the human and the approach does not make interactions with the environment. Therefore, the capacity of the cellular automata approach to make decisions with the changes of the environment is low when compared to the multi agent technology.

Stochastic approaches [15] are based on the probability of the possibility of locating the public services on a particular location. It is difficult to use this approach, to maintain the interactions between the services when a service is located in a particular position. However, the resource dependency and interactions between these public services cannot be modeled through this simulation because once a probability is set it is fixed and the change in the probability may change all the calculations and predictions of the whole system. Therefore, it is difficult to use the stochastic simulation approaches to locate urban public services in an uncertain and complex city environments.

Virtual reality based approaches [22] are based on the human operations to locate public services in the virtual environment. Therefore, whenever, a human change a location of a service, the other services may respond to it by adjusting their locations but cannot interact with the human because, here, the human is considered as a agent who has a very high level of knowledge. In addition, these approaches consume a large amount of resources and memory to create the virtual environment with different services. For example, Hybrid Decision Support System for 3D City Planning [10] needs extra special equipments such as

a stereoscopic monitor, an auto-stereoscopic display or a conventional CRT display in combination with stereo glasses to model city objects.

Comparing & contrasting all these factors, the author has decided that the capabilities of the current approaches to locate urban public services are limited and there is need of proposing a new approach to locate urban public services in a dynamic city environment. During the literature survey, the author has identified that the issue of handling dependencies and complex interactions of the resources while locating urban public services is worthwhile to address because it has been identified that most of the current approaches to locate public services have this issue. Also, the author came into a conclusion that the agent technology has the capability to maintain the complex behaviors of the environment that includes dependencies between the public services and the complex interactions between these services.

2.7 Problem in Brief

Because of the dependency and complex interactions between urban public services such as buildings, roads, water, electricity and telecommunication and the dynamic nature of it, it is difficult for human experts to effectively locate public services manually or using conventional software programs.

2.8 Summary

At the beginning of the chapter, current approaches to locate urban public services were discussed while stating the positive and negative points of those techniques. The entire agent based, cellular automata, stochastic and virtual reality approaches that were considered during the literature survey were compared and their issues were identified. Using those issues, the problem that need to be addressed through this project was identified.