UNIVERSITY OF NAIROBI

COMPUTING THE VALUE OF LAND USING FUZZY LOGIC, A CASE STUDY FROM NAIROBI METROPOLITAN AREA.

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Table of Contents

CHAPTER 1: INTRODUCTION

1.1 Background

This paper presents uncertainty modeling in land valuation using fuzzy logic through the use of membership functions and fuzzy system rules. The value of a piece of land is both the worth of the land itself and any improvements that have been made to it. Valuation is the analytical process of determining the current or projected worth of land. The process of determining the current or projected worth of a parcel of land is what if referred to as land valuation. This is not an easy to compute value as several variables determine the output. Thus one of the greatest challenges in land transactions is accurate valuation. In cities like Nairobi Metropolitan Area, where nearly all land sales data represent transfers of land with improvements, it is very hard to distribute prices between land and building components due to these variables. Fuzzy logic technique; a sub-branch of Artificial Intelligence, is a very useful concept in dealing precisely with problem of land valuation.

Keywords: Fuzzy Logic, Value, Valuation, Land, Assessors, Inference engine, Defuzzification, Fuzzification.

1.2 Problem Definition.

From past experiences, there is no common understanding of how professional land assessors arrive at a value of land, they come up with different values for the same piece of land depending on the reason for the valuation or depending on their assessment and experience. Based on these biased ways in which human assessors calculate the value of the land using various and different mathematical models, it has resulted in skepticism as to the practicability of this process and has become a major stumbling block in land transactions. This has led to practical problems of land assessment and have in many instances led stakeholders to lose money in the course of purchasing land, since many times it is overestimated or underestimated at the time of sale based on the model chosen by the assessor. In practice land assessors calculate the land value based on various variables inputs that are imprecise using mathematical models and formulas of their choice, these inputs vary depending on various aspects: location, development of the property, size of the land, usage of the land, topology, type of soil, frontage among others. These variables inputs when collected over years, make a knowledge base, and with the aggregation of all these input functions, output membership functions can be calculated using a fuzzy logic system. The output is a value of the land.

1.3 Research Objectives

1. To identify what key criterial and inputs determine the value of land, collect required data, and create a knowledge base.
2. To define system rules that apply to land assessors for use in the system.
3. To develop a land valuation system using the fuzzy logic concept.

4. To analyze, organize, and evaluate the performance of the fuzzy system.
5. To determine the optimal value of land using the designed fuzzy system.

1.4 Justification

The problem of valuation can be addressed through the application of fuzzy logic concept, a branch of knowledge representation and reasoning in artificial intelligence. Fuzzy logic is based on the observation that people make decisions based on imprecise and non-numerical information like in the case of land assessors. They are mathematical means of representing uncertainty, vagueness and imprecise information. These sets have the capability of utilizing data and information inputs that are fuzzy and uncertain like in the case of land valuation. It is not possible to determine the exact value of land due to varying inputs used in the process. However, this could be possible with fuzzy functions and rule-based system, through the use of knowledge base obtained from the various inputs defined, the system will be able to efficiently calculate a final value that is reliable and objective. Fuzzy logic is efficient to make machines more intelligent as it enabled reasoning that resonates with that of human land assessors. This concept imitates human reasoning in decision making by providing the capability to judge several criteria inputs. The study will provide a multi-valued logic to a machine that will improve valuation service delivery and instead of using the complex mathematical models and valuation formulas and methods, it will enable this to be done by a machine and open the use of intermediate linguistic variables. This will improve the process, reduce human discretion, and saves the concerned person cost of hiring a professional assessor when it comes to the valuation of land. It will provide for the determination of fair market value ensuring that all land is disposed of or acquired in a manner that protects the interests of both parties, the seller, and the buyer. It will enable persons to acquire land to access the land value before investing in the property and for landowners to know the fair market value of their property in case they need to use it as collateral or to sell. This modeling can be thought of as a first-order approximation to imprecision.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The land has always played a major role in every country, both as a factor of production and as a source of revenue through the collection of duties based on land value for government and. It is also an important factor when it comes to investments. Over the course of many years, various researchers have researched and published different work on the application of mathematical and technology applications like GIS and mathematical modelling in land valuation.

2.2 Existing Work

In 1999, Richard D. Ward, James R. Weaver, and Jerome C. German described well the use of more sophisticated and less expensive GIS technology with the potential for full integration with

computer-assisted mass appraisal(CAMA) models for spatial analysis. They made the initial attempts to quantify the location and qualitative variables during a land assessment. However, there is still no generic best practice when it comes to land valuation and particularly in developing countries. One such case is the Nairobi Metropolitan Area.

According to Syagga, P.M. (1999), the land is a commodity that often requires assessment to determine what is being transacted. The valuation approaches need to be more objective in giving an estimated value. The author elaborated well on the need to use sophisticated tools, analysis, and methodology to come up with objective land value. He concluded by recommending the use of GIS and user interactive search for comparable. From this paper, even though many years have passed by, it is evident that there is a need to employ intelligence and technology to come up with objective land value.

The land valuation system provides control of properties as well as guides taxations which has many benefits. Properly calculated tax rate helps efficient use of land. This is according to Hrvoje, T Mastelic, I, and Ante, R (2006). From this work, an efficient land valuation system is very important in land management. This research was concerning the collection of duties for the government and if the same is done for the public, it could improve the process that is currently in use. A thorough review of the literature reveals that the application of modern technology to value a parcel of land is recommended.

Ungayi, H. M. (2019) studied and analyzed the effect of selected economic factors on real estate market in Kenya. This included house prices in Kenya have continued to rise over the past years. This factors also affects the land prices and this work elaborated on how this factors affect the real estate in Nairobi

Fuzzy set theory was introduced by Zadeh (1965) as an addition of the classical set theory, this concept as describe in his work allows the processing of vague information using the membership concept (Adriaenssens et al., 2004). Zadeh observed that conventional computer logic was incapable of handling data representing vague human ideas Thus this field shows great potential to benefit many domains. Fuzzy logic can be highly suitable to describe key features of a piece of land. This fuzzy logic based on the wide research and publication made by Zadeh confirms to be an area with potential of many domains as the world is field with uncertainty.

Zhi, L., and Han-Xiong, L. (2005) designed a fuzzy logic system from the existing fuzzy structure and applied to modeling and control of complex processes under incomplete dynamics in the manufacturing industry. Using a unique fuzz grade, time and probability the probabilistic processing features can be added into the existing fuzzy configuration to construct a probabilistic fuzzy inference engine. Thus, this developed probabilistic fuzzy logic system (PFLS) was able to learn uncertain information in both fuzzy and stochastic nature. The proposed PFLS by the authors showed that the fuzzy logic can be applicable in areas with imprecise information.

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2.3 Gap

The primary question in this valuation process is how accurate can the value be computed can be. Another major challenge is how to develop the required knowledge base to be used as inputs and come up with rules. Also how to elicit the rules, and how to validate the accuracy of the methods is still an ongoing effort strongly related to the application of fuzzy logic. The problem of assessing the quality of fuzzy data is a difficult one. This is why fuzzy logic rule based system and use of inference engine on a knowledge base is a highly promising possibility within the valuation application area but still requires more research to achieve its full potential. And thus the need for more research in this area on how to improve the use of fuzzy concepts and in this case in the domain of land valuation.

2.4 Linking existing work with your proposed approach

In 1999, Richard D. Ward, James R. Weaver, and Jerome C. quantified the location in the research and this could be expounded using fuzzy logic to have more variable inputs like development quantified. Also, there has been a number of applications of fuzzy logic as evident by Adriaenssens et al., 2004 and this application have been increasing significantly. The applications include medical diagnosis system development, decision-support systems, and portfolio selection. Zhi, L., and Han-Xiong, L. (2005) applied fuzzy logic system designed for manufacturing showed that this concept can be applicable in a similar area which in this case is the land valuation. To this effect it is evident that there has been research in use of fuzzy logic. Based on the work that has been done, many techniques have been applied in this area including mathematical modelling and developing formulas that are in use for valuation at the moment. Using fuzzy logic with these techniques will improve valuation process based on the application to imprecise information. The basic principles of land valuation that already developed will be applied, these already developed models and formulas are very important in this study and provide a basis the use of fuzzy logic to further the work already done. This paper presents how the valuation process can be improved.

CHAPTER 3: METHODOLOGY

3.1 Introduction and the general methodological approach

The reason we have chosen fuzzy logic applications in determining the value of land is that the process provides for acceptable reasoning for imprecise information. Such cases can be handled by this concept. Fuzzy logic provides for representation of expert reasoning like that of the land assessor to be done by the system. In fuzzy models, an object can belong to a set partially. A fuzzy logic system maps variable inputs into variable outputs using the theory of fuzzy sets. An inference engine works with fuzzy system rules. The engine takes inputs, some of which may be fuzzy, and generates outputs, some of which may be fuzzy.

Fuzzy logic starts with the concept of a fuzzy set. Fuzzy set is a set without a crisp, clearly defined boundary. A fuzzy set is a pair $\{(X,m)\}$ where X is a set and μ m:X $\rightarrow$ [0,1] is a membership

function. The fuzzy set concept The difference between crisp and fuzzy sets is conventional by introducing a membership function. Consider a finite set $X = \{x_1, x_2..., x_n\}$. In classical set theory, such a set cannot be defined. An element that belongs to a subset of it does not. In fuzzy set X $Z(X) = (0...,0.4, ..., 1)$. When using this theory of fuzzy logic, we generalize and allow explanations of this type of membership. To explain the set $X = \{x1, x2..., x_n\}$ above, the set element x_1 belongs to the set X only to some extent. The degree of membership is conveyed by a real number between the interval [0, 1], in this case, 0.4. The membership function defines how input to the fuzzy system is mapped to values between 0 and 1. Input is usually termed as Universe (U) as it can contain any value.

Land value is issued based on fuzzy inputs just like the example above. These inputs are location, development of the property, size of the land, usage of the land, security in the area, topology, type of soil etc. Rule combination with the activity of each output membership function known; all output membership functions must be combined. This is typically done using defuzzification. Finally, to get a real-world value, we return to crisp logic from the world of fuzzy membership functions. For this example, the centroid method will be used. The result is the value of a property. Using fuzzy logic, the predetermined inputs can then be defined as follows: Fuzzy logic principles will be used to classify property data such as property characteristics, assigning each point membership in each cluster. This can be very powerful compared to traditional hard-threshold clustering where every point is assigned a crisp, exact label. The fuzzy logic system takes in the various inputs and the output from this function can be repurposed to classify new data according to the calculated clusters. These rules will be set and the fuzzy control programs inbuilt in systems that are used to do the valuation of the property and giving the output on a user interface. To do this, the system will be given the input data and using a defuzzifier it generates an output value. The expert system architecture consists of three parts: A knowledge base represents knowledge in the domain under the study and rations all the facts and rules about a particular problem in that domain. An inference engine on the other end is a set of algorithms, which perform reasoning, and decision-making. User interfaces, for a user to interact with the expert system. This system will apply the fuzzy set to come up with the output, which is the value of the land-based on the crisps inputs: size, location, and developments in this case. These inputs can change or vary.

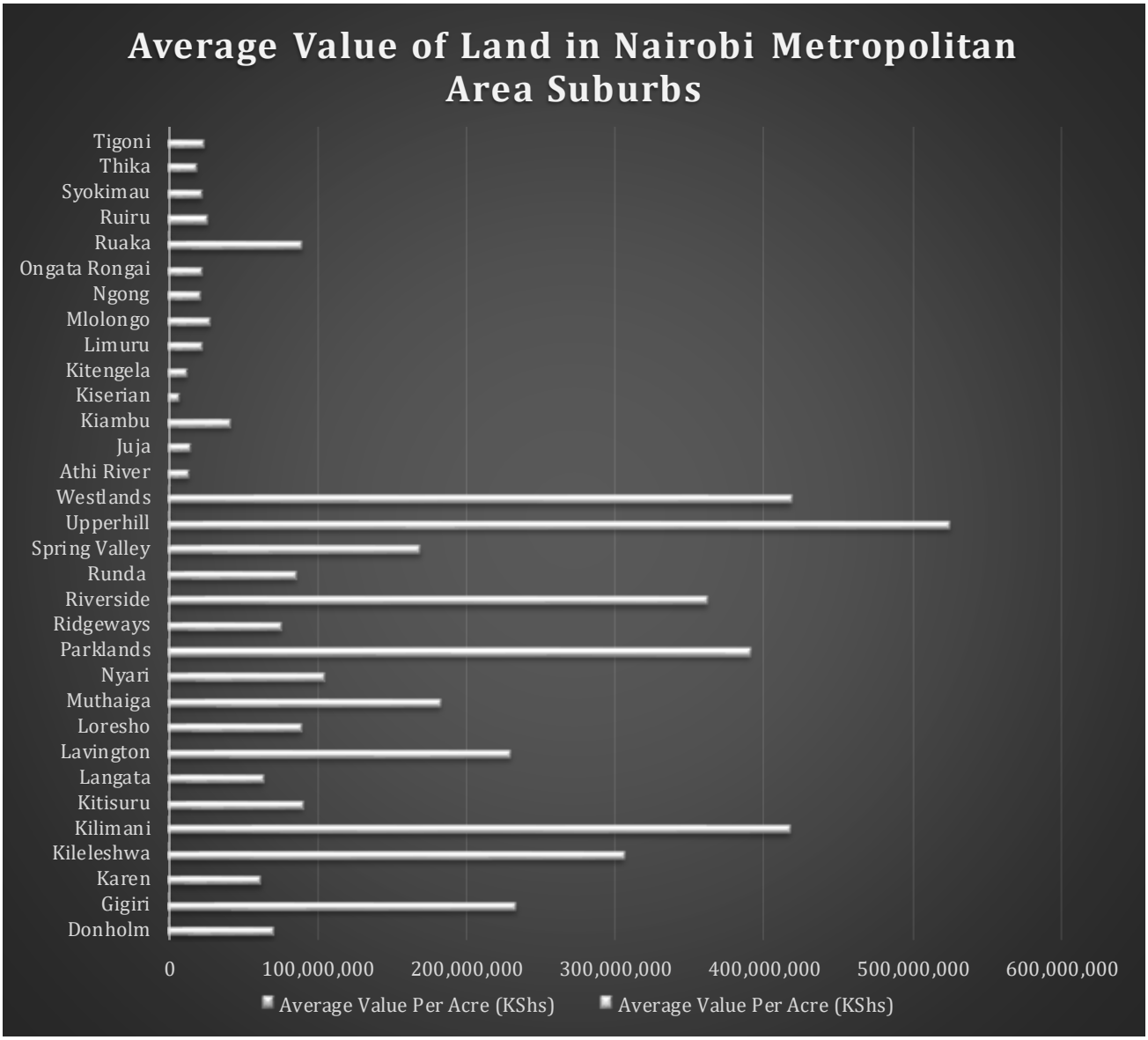
3.2 Participants and sample size

This study used secondary data collected from the Hass Land Index from 2007 to 2017 and observation method to collect the key criterial inputs. This secondary data from Hass Land Index measured the prices of land and its value per acre in Kenya shillings in 32 suburbs of Nairobi Metropolitan Area. The data is available as provided by Hass Consult Limited for the public. It is a fair sign of the past and current Kenyan land value. Observation of the developments in Nairobi suburbs were also used to collect data on developments used and arrive at the key inputs as location, size and development for this study.

Population - Land Prices for Nairobi Metropolitan Area

3.3 Data collection and analysis methods and validations.

Using the statistical analysis methods, the collected land values per acre was analyzed using python and Microsoft excel to identify key criterial inputs that affect the land valuation and calculate the average prices that will be multiplied by the valuation factor computed through fuzzy system to get the final value. From the data collected and reports analyzed the factors that affect land value in Nairobi include location of land, developments and infrastructure, security. From the analyses, an acre in Upper hill and Illimani are of high value. This is majorly due to proximity town and thus the location in a very key input, also the developments in the area.



Source – Hass Land Index.

Findings

Sample - 32 Nairobi Suburbs and Satellite Towns Land Price
Data Obtained from Hass Index
Parameter - Average cost of an acre on Nairobi Suburb μ
μ = 62M

3.4 Conceptual Design and Framework.

Independent Variables (x)
Size, Location, Accessibility, Development, Level, Topology, Accessibility, and Shape
Dependent Variable (y) – Value of Land

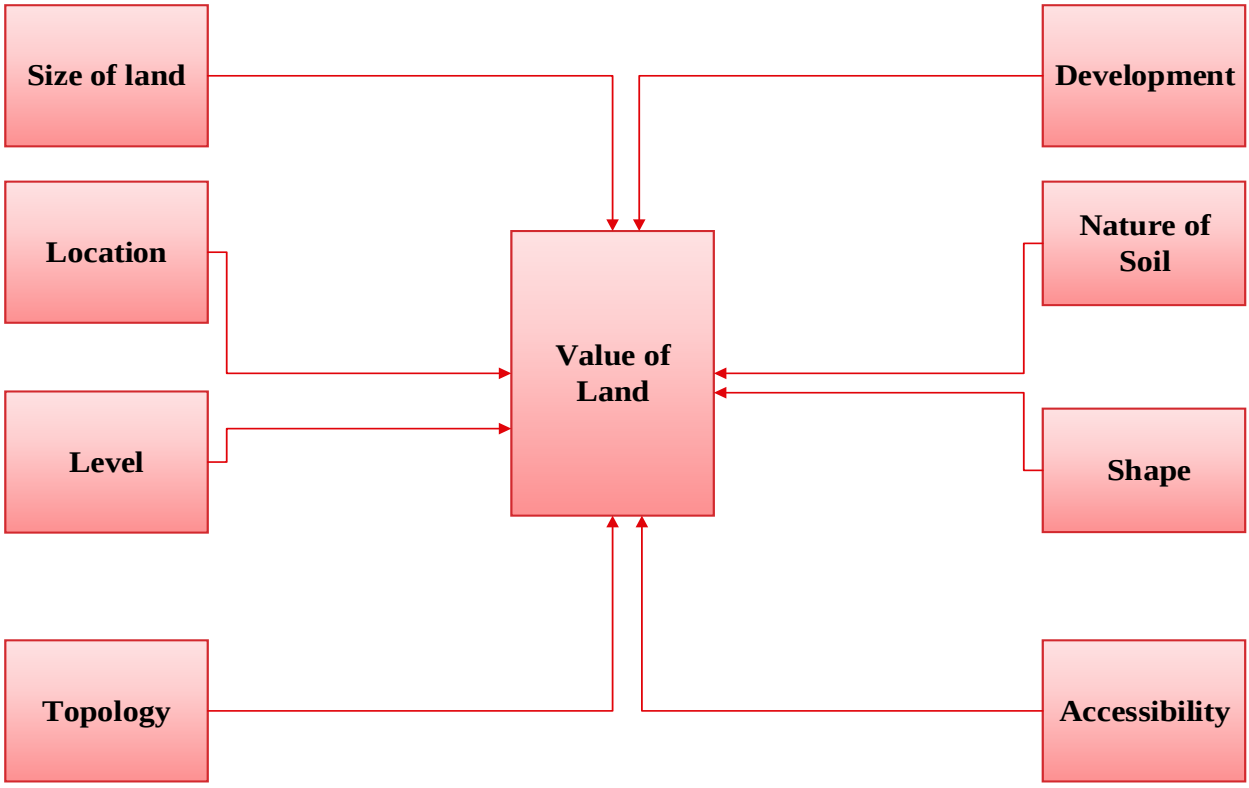


Figure 1: Conceptual Framework

The steps followed in using fuzzy logic in land valuation process will be as follows.

Specify Input and Output Variables

These valuation inputs can vary. These variables play a very important part in the decision about how much is the value of the land. For this case of Nairobi Metropolitan Area, key inputs identified in the analysis include; location of land, size of land and development of land. They will be used in the system as follows:

i. Location of Land

Universe (ie, crisp value range): Location of the property

Fuzzy set (ie, fuzzy value range): poor, average, good, excellent

ii. Size of Land

Universe: What is the acreage size of the land or property in question_

Fuzzy set: 1/8,1/4.1/2,1, 2…, n

iii. Development on Land

Universe: What is the development level. This is a fuzzy input as it can lie between boundaries

Fuzzy set: poor, average, good

The output variable is simply the land value amount.

Value of Land

- Universe: How much value is the property in the amount?
- Fuzzy set: Amount.

Mapping the identified inputs to compute the output land factor.

Specify Membership Functions

Membership functions are the context-dependent use to map the non-fuzzy values. For land valuation development variables inputs above, the membership functions are as shown below

- Land Valuation (size)= 1/8,1/4.1/2,1, 2…, n}
- Land Valuation (location)= {poor, average, good}

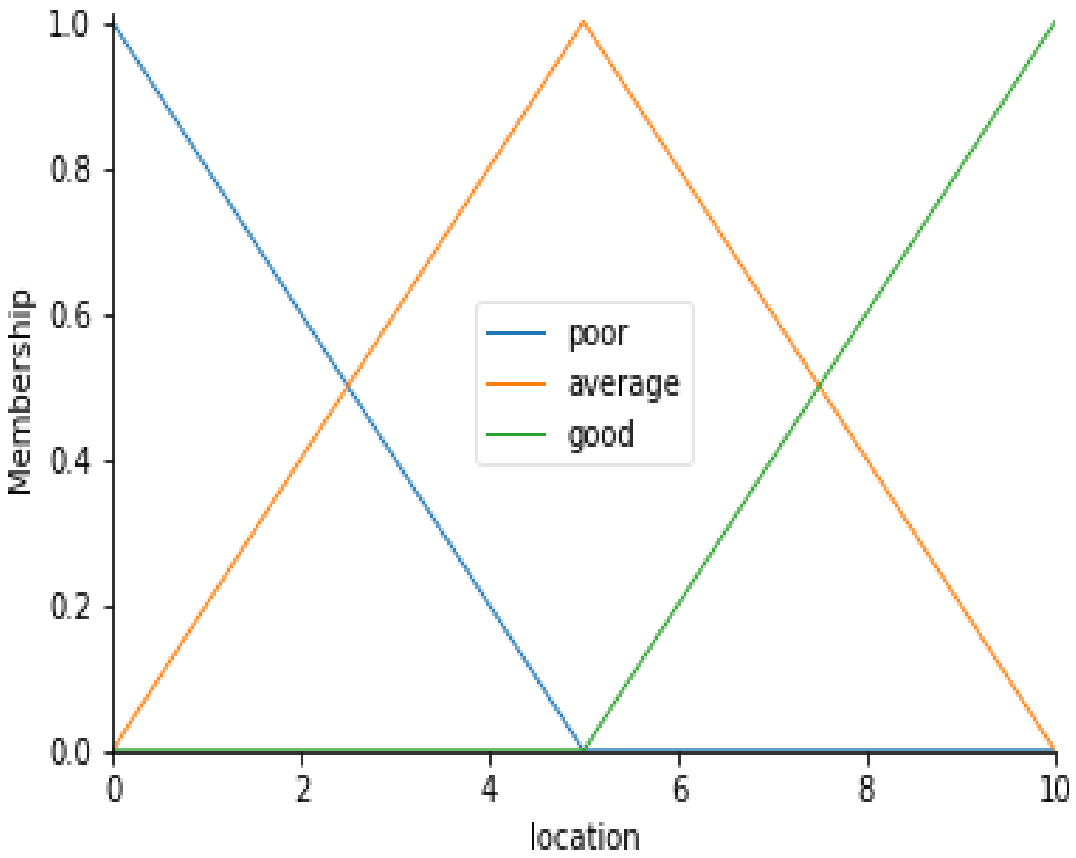


Figure 3: Location membership

- Land Valuation (development)= {Poor, Average, Good}

Visualization of the membership functions

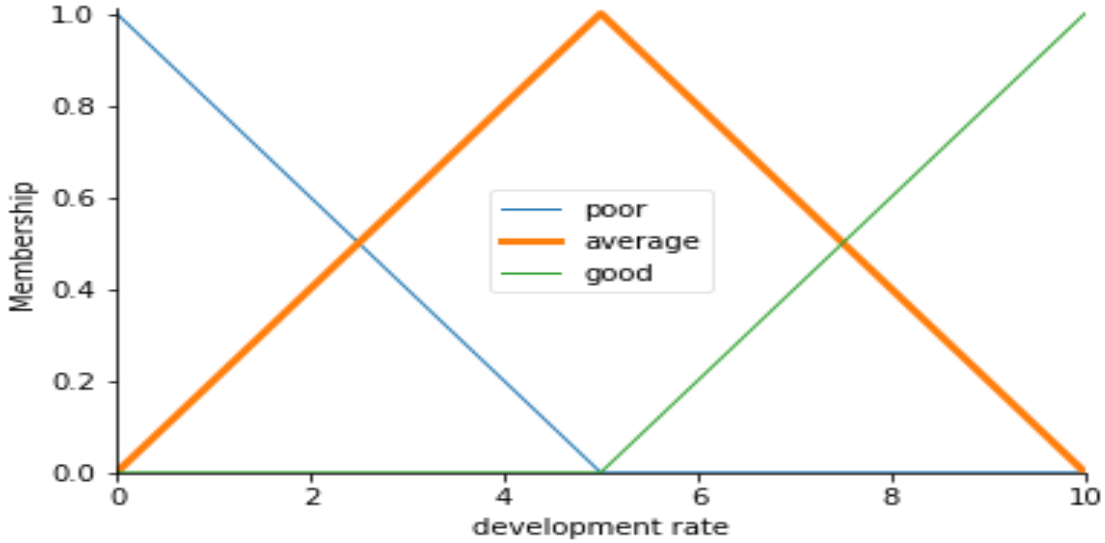


Figure 4: Development Rate membership.

- Output Value

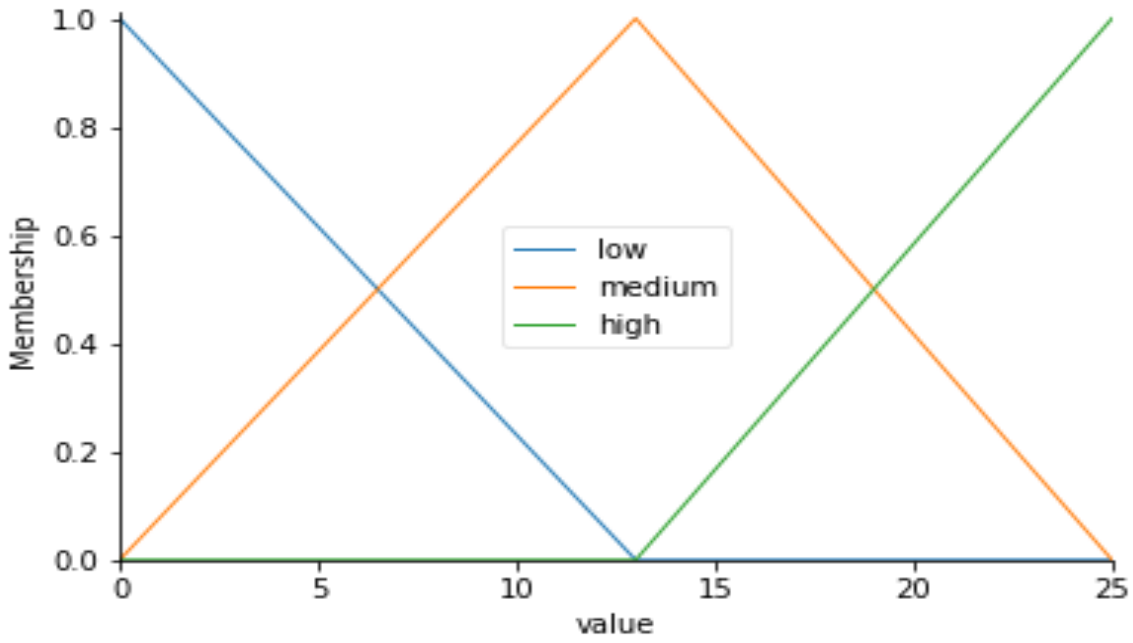


Figure 5: Value of Land Membership

Specify Fuzzy Rules

Most people would agree on these rules, but the rules are imprecise. Representing the imprecise rules into a defined value of land is challenging. That is why fuzzy logic would excel in this rather than human assessors. The rules used in this research are as follows:

- IF the size of the land is big, THEN the score will be good.
- IF the location is excellent, THEN the land value will be high
- IF the location is poor and the development of land is good THEN the value will be medium.
- IF the location is good THEN the value will be very

Medium

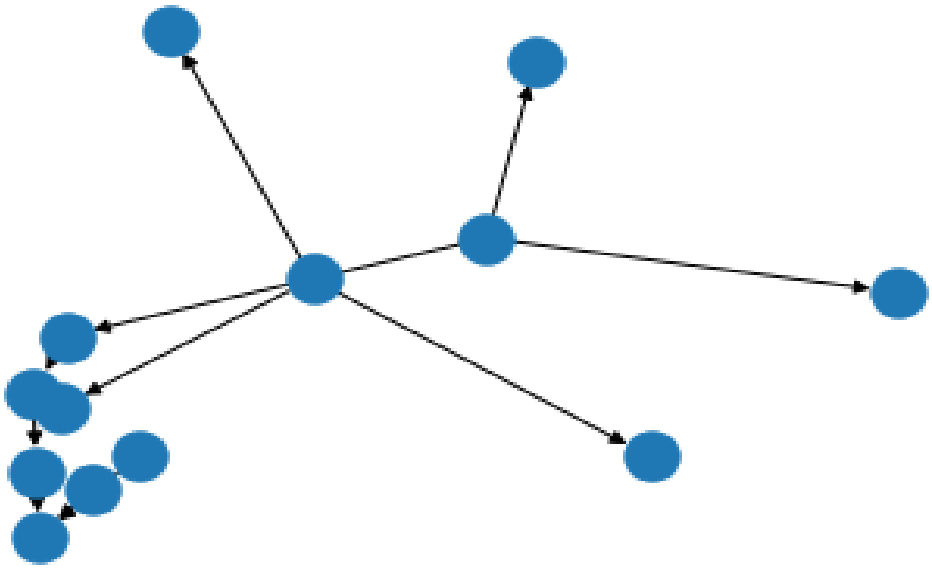


Figure 6: Simulation of the inference engine created using python.

Construct Custom Fuzzy System for land valuation, Evaluate and Visualize Fuzzy System.

So having the variable inputs defines, rules define, the designed fuzzy logic system as shown below will be able to compute and give an output value.

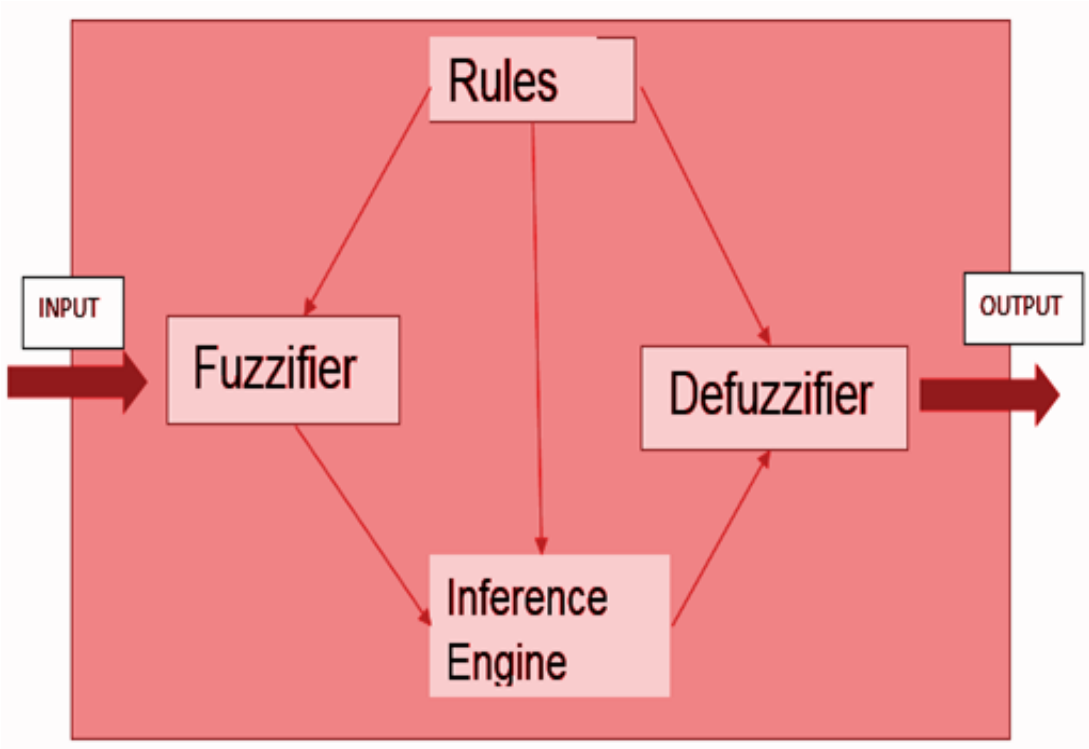


Figure 7: Fuzzy logic implementation process

a. **Fuzzifier** − It transforms the system inputs, which are crisp numbers, into fuzzy sets
b. **Knowledge Base /Rules** − It stores IF-THEN rules provided by experts.
c. **Inference Engine** − It simulates the human reasoning process by making fuzzy inference on the inputs and IF-THEN rules.
d. **Defuzzifier** − It transforms the fuzzy set obtained by the inference engine into a crisp value.

CHAPTER 4: EXPECTED RESULTS AND OUTPUTS

4.1 Introduction

How the fuzzy system for land valuation will work.

The power of fuzzy systems is allowing complicated, instinctual behavior based on a sparse system rules. The membership function universes were coarse, only defined at the integers, but functions membership allowed the effective resolution to increase on demand. This system responds at random to small changes in inputs, and the processing burden is minimal. And it involves all intermediate possibilities between 0 and 1. It tries to mimic human-like decision making, which can incorporate all values in between True and False. Fuzzy logic helps to solve a problem after considering all available data. Then it takes the best possible decision for the given input. Fuzzy theory can capture the impreciseness of linguistic terms in statements of natural language. This provided a greater capability to model human common-sense reasoning and decision making. The Fuzzy logic works on the levels of possibilities of input to achieve a definite output.

4.2 The nature of the end product

To simulate a land valuation rule-based system designed above, we create a simulation using an example to demonstrate how this technique will work. Think of this object representing our controller applied to land values. The order in which the rules are presented here is arbitrary. It does not matter which rules come first. These rules are the core of the output value and they correspond to the rules for a fuzzy logic system. When you give mathematical meaning to the linguistic variables you have a complete fuzzy inference system. The methodology of fuzzy logic must also consider how are the rules all combined. These variations provide the basis for the rules to be used in the system.

If the fuzzy rule based system is given the location of a piece of land as 6.5 and the development rate as 9.8, it would recommend value factor the property and this can be used to come up with value of land. Based on the output below it will give a valuation factor of 2 which is medium and is thus multiplies by the average price of an acre of land which is 62 and thus the land value will be 20/25 * 62 which come to 107 M.

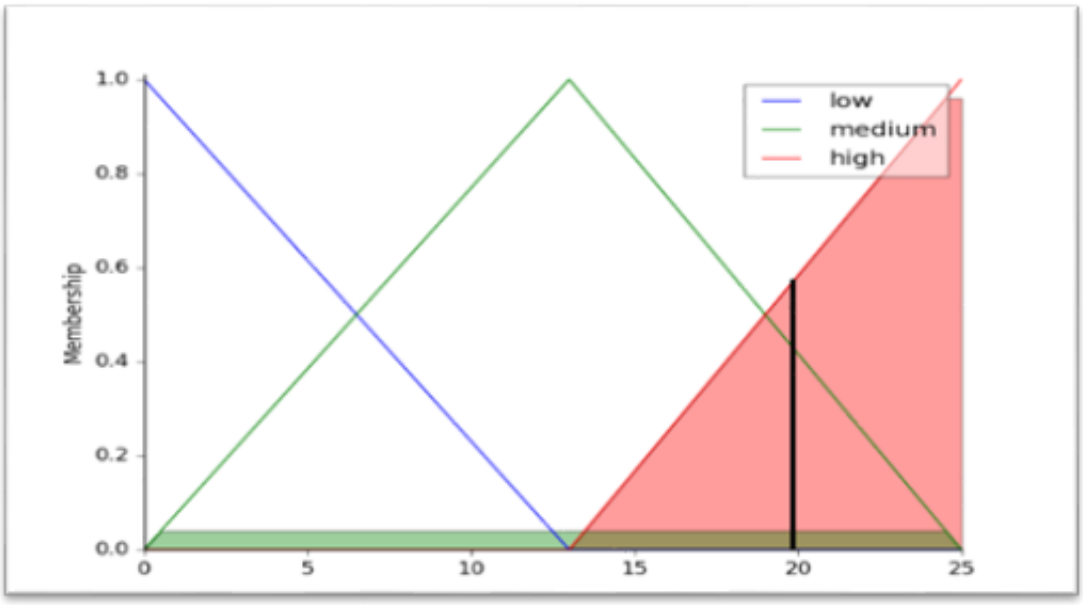


Figure 8: Fuzzy System Performance Analysis

The system will be able to be tweaked by adding or changing rules, inputs, and adjusting the set boundaries in the inputs until the efficient system performance is achieved. This system, unlike the traditional systems, will be using knowledge rather than data in the determination of the value of the land. This will improve the capacity of human resources available; increase transparency in valuation process. The ability to also enable the use of vague categories such as development in a city will be a great improvement to existing processes. This rule-based system will be inbuilt in existing web-based applications and thus useful as it makes scalable to incorporate future changes in policy and knowledge. Valuation is currently a manual process where a human expert spends a huge amount of time performing a single computation of land value based on vague inputs that are considered.

Advantages of using fuzzy logic in valuation.

i. Fuzzy Logic can work with any kind of input even if it is unstructured, distorted, imprecise, or contain noise which is the case in land valuation where we are dealing with inputs such as security, development and location.
ii. Fuzzy Logic design is very easy to comprehend and use as it closely mimics the way the assessor's decision-making.
iii. Fuzzy Logic System needs a very little amount of data to prepare a robust model.

4.3 Conclusion

The land is an atypical type of asset because, in the vast majority of cases, it is extremely difficult to come up with a reliable value for this type of property. So how are we supposed to have any confidence in the value of what we are buying? This paper presented the method of calculating the value of a property based on several inputs and characteristics of the property; through the use of

this logic, the knowledge based system can efficiently define a value for the land. Future improvements can include the use of GIS to have the exact location, size, and spatial information of the land. Semantic networks will be very important in the system to map out property ownership by several individuals and this can be key in understanding property ownership. Fuzzy Logic provides an alternative way to approach real-world problems in the computing world. It can be easily applied to different applications and control systems which can reap long-term benefits. Given its ability to work well with a variety of problems, it opens a lot of doors to modern computing. However, it also has limitations just like other methods when it comes to accuracy and its inability to learn from its failure.

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