Addressing Uncertainty in Property Depreciation Rate Estimation Using Fuzzy Logic Modelling

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Key Words: Property Valuation, Depreciation Rate, Fuzzy Logic

SUMMARY

Valuation of immovable property or real estate is critical to businesses transactions and, is done in order to facilitate different purposes including; property transfer, mortgage, rent assessment and compensation. Determination of rate of depreciation though subjective, is a critical aspect of property valuation process especially in the application of the Depreciated Replacement Cost or Cost Method for determination of Market value of a property.

Currently, estimation of depreciation rate is based on personal opinion of the appraiser (valuer). Basically, estimation based on personal opinion is subjective and inherently uncertain and imprecise. This brings about disparities which exceed acceptable limits to property values in case the same property was appraised by more than one person.

This paper investigates applicability of Fuzzy Logic concepts to address imprecise and uncertain estimation of depreciation rate during property valuation and improves the current model for property valuation by estimating depreciation rate using Triangular Fuzzy Numbers (TFN). The results obtained with Fuzzy Logic modelling have been compared with those arising from a deterministic approach through the use of crisp numbers. Results show significant improvement in precision of estimates of depreciation rate when Fuzzy Logic approach is adopted.

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1. INTRODUCTION

Property valuation is the technique of estimating and determining the fair price or value of a property such as land, building, factory, and other structures. Valuation of immovable property or real estate is critical to businesses transactions and, is done in order to facilitate different purposes including; property transfer, mortgage, rent assessment and compensation. The most common approaches used for real property valuation include cost approach, sales/market comparison approach, and income approach. They are all based on the economic principles of price equilibrium, anticipation of benefits or substitution.

When selecting appropriate valuation approaches and methods the appraiser considers the following factors;

i. Appropriate bases of value determined by the terms and purpose of the valuation assignment
ii. Strengths and weaknesses of the possible valuation approaches and methods,
iii. Appropriateness of each method in view of the nature of the asset
iv. Approaches or methods used by participants in the relevant market
v. Availability of reliable information needed to apply the method(s)

Despite of the specified details for arriving at a fair price or value of a property using the above mentioned approaches, there is always an element of uncertainty in the determination of property value. By nature, estimation is based on the opinion of the appraiser which is subjective and brings about disparities to property values in case the same property was appraised by more than one person.

Determination of rate of depreciation though subjective, is a critical aspect of property valuation process especially in the application of the Depreciated Replacement cost or Cost Method for determination of Market value of a property. Depreciation is the difference between the cost of replacement or reproduction and the present value of an improvement. It measures the total loss in value from all causes that have occurred as of the date of valuation.

The main challenges facing appraisers in the determination of rate of depreciation include, inter alia, unavailability of up-to-date data on construction costs; inadequate data for calculation of depreciation; mostly depreciation rate are based on opinion and physical appearance of the property increasing uncertainty and thus imprecise estimation of the depreciation rate of properties. Moreover, currently there is no consensus as to which of the given range of values is to be used when estimating accrued depreciation in order to adequately address the key depreciation indices that is age, level of physical deterioration, functional and economic obsolescence (Bello I.K. et al, 2015).

In this aspect, there is a need to investigate approaches that can address uncertainty/ subjectivity during property valuation to ensure that valuation reports are reliable, consistent, and accurate considering that, valuation aims at estimating and determining the fair price or value of properties such as land, buildings, factories, and similar structures. Fair price is an important factor for equitable property transactions. In this paper, the cost or Depreciated Replacement Cost approach is the method of choice for the case study, specifically for determining depreciation rates for the purpose of compensation of real property. The Cost and Depreciated Replacement Cost approach are used interchangeably so are obsolescence and deterioration.

2. ESTIMATION OF PROPERTY DEPRECIATION RATE

Depreciation refers to the diminished value of an asset as time passes. The effects of time cause a building to gradually become obsolescent (or out of date, aged). This can occur in different ways, including; physical, functional and economic. The contributing factors are due to wear and tear of buildings, technology change, and consumer tastes change. Depreciation is also regarded as the difference between the cost (new replacement or reproduction) and the present value of an improvement. It measures the total loss in value from all causes that have occurred as of the date of valuation. Hoesli and Macgregor (2000) describe depreciations as the loss of rent or capital income of an aging property when compared with an equivalent new property. Depreciation is a composite term consisting of three components; Physical deterioration, Functional obsolescence and Economic obsolescence (RICS, 2005), (IVSC, 2007).

The measurement of depreciation in the use of cost approach methods for valuation purposes has been a subject for several studies. However, currently there is no consensus among researchers as to which of the several approaches is to be used in estimating accrued depreciation so as to adequately address the key indices that are of concern to valuers namely, the level of physical deterioration, functional and economic obsolescence (Taubman and Rashe, 1999), (Hulten and Wykcoff, 2003), (Follain and Malpezzi, 2004), and (Connaday and Sunderman, 2006). A study by Bello et al. (2015), suggests presence of some challenges in the depreciation measurement literature especially in Nigeria, and hence reinforces the need for a thorough research on the subject matter if valuation reports are to be *reliable, consistent* and *accurate.*

The proper estimation of depreciation for valuation purposes within the cost approach to value estimate is of crucial importance not only in arriving at correct estimate of value but also has the potential to reduce the variation (disparity) that usually exist between values declared by appraisals on the same property (Gyamfi-Yeboah et al., 2006). Current approach for estimation of depreciation is based on human opinion, which is intrinsically subjective. This is the main reason for imprecise estimation of depreciation factor, and hence the main source of disparity observed when valuation of the same property is determined by different appraisers. The next section describes how Fuzzy Logic can be used to address uncertainty and imprecision that is associated with estimation of depreciation factors needed for property valuation. It describes an approach that can be used for property valuation by modelling *the rate of depreciation* based on Fuzzy Logic concepts.

3. FUZZY LOGIC

Fuzzy logic was introduced by Zadeh (1975) and allows us to deal with the "vagueness" problem in different areas. Fuzzy logic is less dependent on precise data and thus can be used to solve different kinds of problems. The strength of fuzzy logic is its ability to deal quantitatively with inexact information Chiu and Park, (1994) and is increasingly used in engineering and economic applications. It enables engineers to configure systems quickly without extensive experimentation and to make use of information from expert human operators who have been performing the task manually.

Practical applications of fuzzy logic are not restricted to engineering and related fields. In medicine, expert systems using fuzzy inference can help doctors diagnose diabetes and prostate cancer. Management science, stock market analysis, information retrieval, linguistics, and behavioural sciences are just a few of the other domains where fuzzy logic concepts and techniques have been profitably used (Sangalli, 2013).

Fuzzy logic is becoming an important tool for decision making due to its ability to address imprecise and vague information. This is accomplished by making use of fuzzy membership functions.

3.1 Fuzzy Set Membership Function

Many decision-making and problem-solving tasks are too complex to be defined precisely, however; people succeed by using imprecise knowledge. Fuzzy logic resembles human reasoning in its use of approximate information and uncertainty to generate decisions. To express imprecision quantitatively, a set membership function maps elements to real values between zero and one (inclusive). The value indicates the "degree" to which an element belongs to a set. For fuzzy systems, truth values (fuzzy logic) or membership values (fuzzy sets) are in the range [0.0, 1.0]. The degree of membership of zero and one corresponds to no membership and full membership respectively. Membership in a fuzzy set is usually represented graphically (Figure 3.2). Membership functions are determined by both theoretical and empirical methods that depend on the particular application, and they may include the use of learning and optimization techniques.

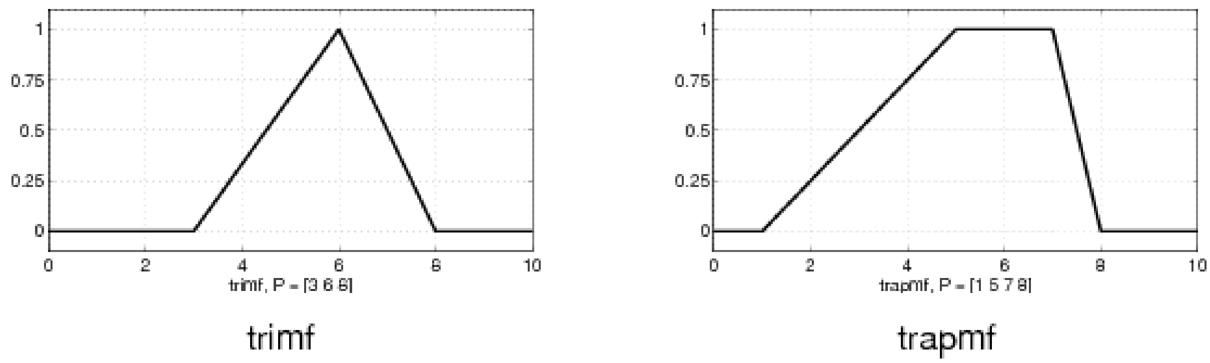

Figure 1 Graphs of Triangular and Trapezoidal membership functions

3.2 Fuzzy Numbers

Exact values such as parameters are rare in real life practice because the information we are able to gather is at best incomplete or imprecise. Fuzzy numbers and fuzzy arithmetic provide a way to model and compute with imprecise parameters (Zadeh, 1975), (Dubois, 1980).

A fuzzy number is an generalization of a regular, real number in the sense that it does not refer to one single value but rather to a connected set of possible values, where each possible value has its own weight (membership function) between 0 and 1. A fuzzy number is thus a special case of a convex, normalized, and bounded fuzzy set of the real number line. The condition of normalization implies that the maximum membership value is 1. In other words, they have a peak or plateau with membership grade of 1, over which the members of the universe are completely in the set, see Figure 2. The convexity property means that the membership function is increasing towards the peak and decreasing away from it.

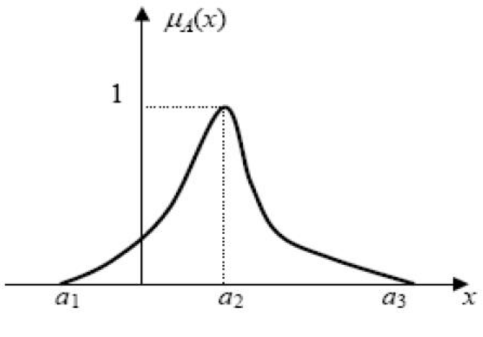

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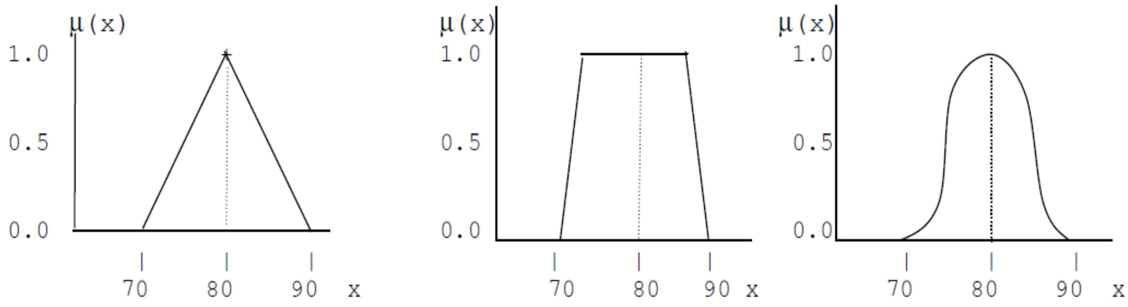
Figure 2 Membership function of a Fuzzy number (a_1, a_2, a_3)

In many respects fuzzy numbers depict the physical world more realistically than single valued numbers. There is no restriction on the shape of the curve; some of the most preferred and frequently used fuzzy numbers are represented by curves (membership functions) shown on Figure 3. The curve in figure (a) is a triangular fuzzy number, the curve in Figure (b) is a trapezoidal fuzzy number, and the curve in figure(c) is bell shaped fuzzy number.



(a) Triangular (b) Trapezoidal (c) Bell-shaped

Figure 3 Popular Fuzzy numbers (a) Triangular (b) Trapezoidal and (c) Bell-shaped

A Triangular fuzzy number has three parameters; smallest possible (a) value, most possible (b) value, and largest possible (c) value. Triangular fuzzy numbers are more natural and easy to interpret and therefore preferred in fuzzy modelling and calculations (Ban et al. 2011). It is for this reason that Triangular fuzzy numbers are applied in this study.

3.3 Centroid Defuzzification Technique

There may be situations where the output of a fuzzy process needs to be converted to a single scalar quantity, for example controllers of physical systems require discrete signals. The process of converting fuzzy values to crisp ones is called defuzzification (Ross, 1995). There are many defuzzification techniques, but primarily only three of them are in common use. They include *Maximum, Weighted Average and Centroid* defuzzification methods (Sugeno,1985), of these; the centroid is the most commonly used and is briefly detailed below.

The Centroid method is also known as center of area or center of gravity defuzzification. This technique was developed by Sugeno (1985). It is the most prevalent and physically appealing of all the defuzzification methods (Sugeno, 1985; Lee, 1990). The centroid defuzzification technique can be expressed as;

$$x^* = \frac{\int \mu_i(x)\, x\, dx}{\int \mu_i(x)\, dx} \qquad (1)$$

Where :x^* is the defuzzified output, $\mu_i(x)$ is the aggregated membership function and x is the output variable. The only disadvantage of this method is that it is computationally difficult for complex membership functions. For a Triangular Fuzzy Number this reduces to

$$\mathbf{X^*} = \frac{\mathbf{x_1+x_2+x_3}}{\mathbf{3}} \qquad (2)$$

Where x_1, x_2, and x_3, are the smallest, most plausible and largest values of the TFN

3.4 Application of Fuzzy Logic in Real Estate Field

Precise estimation of depreciation for valuation purposes within the cost approach to value estimate is of crucial importance not only in arriving at correct estimate of value but also has the potential to reduce the variation that usually exist between values declared by appraisers on the same property Frank et al.(2006).

The approach that is adopted in many valuation exercises is to examine the property in question and take notes of its age, level of maintenance and obsolescence. The appraisers then, make a judgment using his professional expertise, to finally arrive at the rate of depreciation**.**

In doing this, valuation professionals may rely on different models or mathematical relationships to guide them in estimating the rate of depreciation. However, in Tanzanian there is no consensus on the model or approach which when used will help reduce the level of variations in the opinion of appraiser.

The three categories of depreciation of interest to appraisers are physical, economical and functional obsolescence. The approach that this study supports is one that explicitly incorporates all these elements in the process of estimating depreciation. Such an approach provides the appraisers best estimate of accumulated depreciation for any particular property. This study investigates the use of *fuzzy logic modelling* to address uncertainty inherent in the current property valuation practice.

Various studies have explored the applicability of Fuzzy Logic concepts to the real estate field, Bagnoli and Smith (1999) showed the application of Fuzzy Logic to real estate valuation, they went further to providing as a result a fuzzy set output but didn't consider some relevant real estate risk factors. Sun et al. (2008) have used a fuzzy analytical hierarchy process for the evaluation of risk in residential real estate projects using linguistic variables rather than crisp values. Cui and Hao (2006) concentrated on the fuzzy cost approach for real estate purposes and for determining the rate of building depreciation with time. Barranco et al. (2004) experimented with a web-application based on a fuzzy set and applied to real estate management. In their study, real estate attributes were expressed by fuzzy data. In Krol et al. (2007), a Mamdani-type model and a Takagi–Sugeno–Kang-type model have compared fuzzy models useful for real estate appraisal with the aim of determining fuzzy rule bases for both models. They concluded that fuzzy models provide an acceptable solution for real estate appraisals.

3.5 Modelling Uncertainty in Estimation of Depreciation Rate Using Fuzzy Logic

Fuzzy logic can be used to estimate the most probable value from a set of uncertain and or imprecise data derived from experiments and/or our expert knowledge. Fuzzy logic was designed with the ability to deal quantitatively with vague, inexact or imprecise information (Chiu and Park, 1994). In their study, Mwaikambo et al (2015) applied Triangular Fuzzy Numbers (TFN) to estimate the cost of accessing spatial data using imprecise data sourced from expert opinion. Their approach was based on the standard Activity Based Costing model, Kaplan, (2007), and Fuzzy Delphi methodology (Dalkey and Helmer ,1963) .

The standard model for Depreciated Replacement Cost is:

$$DRC = C - D + L, \tag{3}$$

where C = unit cost × gross floor area
D = x% (annual dep.) x n years, that represent the estimated depreciation.
L = value of land as of vacant.

In the present practice, this is given as a crisp (exact) value. However, with fuzzy logic the estimated depreciation is expressed as an approximate value. It is represented by a three valued number, referred to as a Triangular Fuzzy Number;

TFN: D(s,m,h) where
s - Smallest possible depreciation estimate
m- Most probable depreciation value
h- Highest possible depreciation estimate

All three categories of depreciations, namely; Physical, Economical and functional, are modelled in a similar fashion. The Fuzzy Model for DRC becomes;

$$\mathbf{DRC = C - D(s, m, h) + L} \tag{4}$$

The integrity of the standard DRC model is maintained. Fuzzy logic is only used to provide the best possible depreciation values that ensure more reliable estimate for the value of the property. The next section describes a methodology used to test the applicability of model and specifically, to test improvement in precision of depreciation estimates introduced by fuzzy logic modelling.

4. ESTIMATION OF FUZZY DEPRICIATION RATES

In order to test applicability of the proposed model for estimation of fuzzy depreciation rates, the study sought to compare results obtained by using, Fuzzy Logic approach and by conventional method. The selected property for testing was old building built in early 1940 used for office and commercial purposes. Eight (8) appraisers were asked to record what they estimated to be most probable value for the depreciation rate of the building. This value would be the one obtained as in conventional valuation practice. Then the appraiser ware asked to provide two more values, one representing the smallest possible value for the depreciation rate, and another for the highest possible depreciation rate. The three valued number constitutes a TFN for the fuzzy depreciation rate. The exercise was carried out by one appraiser at a time to avoid one person influencing estimation of another. Tables 1 to 4 below depict fuzzy estimates for depreciation rate of the building for each of the three categories i.e. Physical, Economical and Functional.

For each TFN, a crisp value was computed using the simplified centroid defuzzifier formula (2). Standard deviations were computed for the plausible value and the defuzzified value in order to measure disparity among estimates supplied by all eight respondents. The exercise was repeated for all three types of depreciation rates. Data collected is presented in the following tables which also include processed statistical results and graphs.

. 4.1 Results

Table 1 Physical deterioration Estimation TFN’s

Staff Identity	**Minimum Value (%)**	**Plausible Value(%)**	**Maximum Value(%)**	Deffuzzyfied Value
No	**Amin1(i)**	**Ap1(i)**	**Amax1(i)**	Mean(i)
1	10	15	50	25
2	30	35	50	38
3	25	30	35	30
4	10	20	25	18
5	20	25	40	28
6	15	30	35	27
7	15	35	45	32
8	20	25	40	28
Mean	18	27	40	28

Table 2 Economic deterioration Estimation TFN’s

Staff Identity	Minimum Value (%)	Plausible Value (%)	Maximum Value (%)	Deffuzzyfied Value
No	Amin1(i)	Ap1(i)	Amax1(i)	Mean(i)
1	25	35	40	33
2	30	40	60	43
3	10	15	25	17
4	25	30	40	32
5	25	40	50	38

6	25	35	45	35
7	25	40	50	38
8	20	30	45	32
Mean	23	33	44	34

Table 3 Functional deterioration Estimation TFN's

Staff Identity	Minimum Value (%)	Plausible Value(%)	MaximumV alue(%)	Deffuzzyfied Value
No	*Amin1(i)*	Ap1(i)	Amax1(i)	Mean(i)
1	10	15	50	25
2	30	35	50	38
3	25	30	35	23
4	10	20	25	18
5	20	25	40	28
6	25	30	40	32
7	25	30	35	30
8	15	25	30	25
Mean	20	23	38	27

Table 4 Mean Depreciation Values

Category	Smallest	**Most Probable**	largest	**Defuzzified (crisp) value**
Physical	18	**27**	40	**28**
Economic	23	**33**	44	**34**
Functional	20	**23**	37	**27**

Table 5 Standard Deviations

Category	Most Probable Value	Defuzzified value	Disparity Decreased to
Physical	7	5	71.4%
Economic	10	8	80.0%
Functional	11	9	81.8%

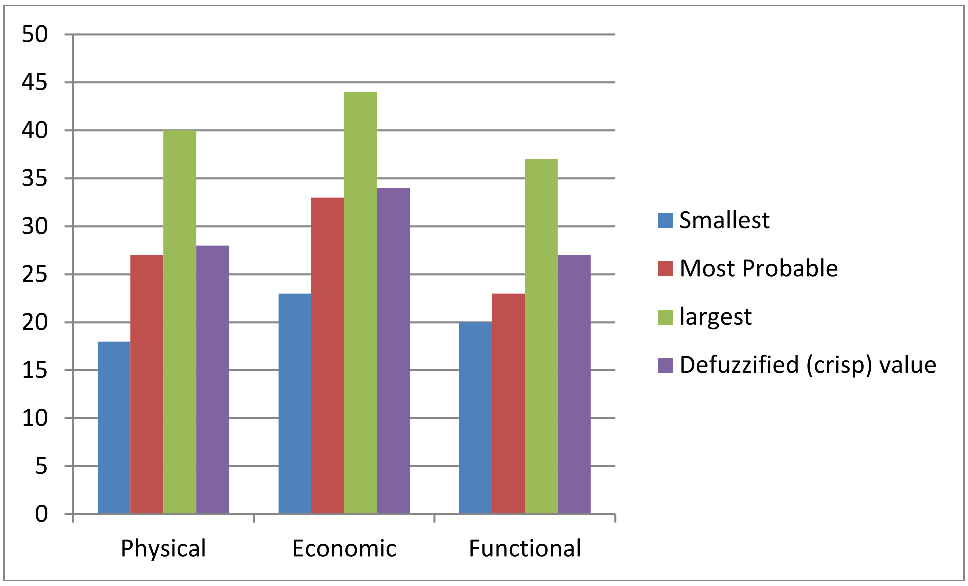


Figure 4 Shows relative magnitudes for smallest, most probable, largest and deffuzified values.

There is a slight difference between the values of the estimated and defuzzified rates, indicating that the fuzzy values are increasing compared to the non-fuzzy estimates. In this study, the effect of uncertainty of depreciation estimates tended to lower the depreciation rate. This implies that the resulting property values would have been reported higher than realistic values

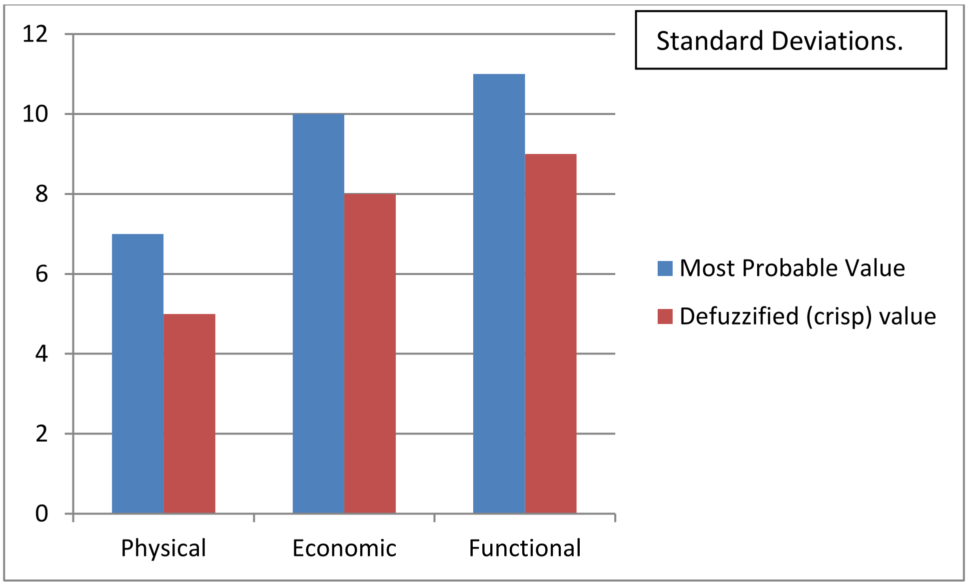


Figure 5 Standard deviation showing disparities between ordinary and Fuzzy estimations

Disparity among appraisers is lower when Fuzzy estimations are used compared to ordinary estimation without TFN's. The analysis indicates substantial decrease in disparity (71.4% for physical, 80% for economic and 81.8% for functional depreciations respectively) for the Fuzzy values compared to the probable (ordinary) values (Table 5). This shows that Fuzzy logic modelling improved precision of the estimates and thus it leads to more accurate property values.

5. CONCLUSION

The proposed approach does not in any way change the standard way of calculating the Depreciated Replacement Value, addresses the way depreciation estimates are arrived out

It is common practice for appraisers to estimate the rate of depreciation by observing the physical appearance of the property and submit their opinion. In this study, Fuzzy logic is used to address imprecision and uncertainty inherent in human judgment when estimating rates of depreciation using Triangular Fuzzy Numbers to arrive at reasonably more accurate results. Triangular Fuzzy numbers have been chosen because they are intuitive, easy to understand and use.

The study has demonstrated the applicability of Triangular Fuzzy Numbers to improve precision of property depreciation rate estimation, and thus allow more accurate determination property values especially where a fair cost value is to be established. This study has showed that fuzzy logic modelling ca be applied to address imprecise and uncertain estimation of depreciation rate during property appraisal and improves the current model for property valuation. The results indicate that by using Fuzzy logic approach, it is possible to reduce disparities observed when a property is appraised by more than one person.

This study adopted Triangular Fuzzy Numbers for modelling rate of depreciation in the establishment of Cost Value using DRC. This was due to convenience and simple computations demanded by TFN. However, it is recommended that future research should investigate the applicability of Trapezoidal Fuzzy Numbers defined by four parameters namely; smallest value, interval, and largest value; as such they are more accommodating in modelling uncertainty than TFN.

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