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A dynamic decision-making model in property valuation in South Africa

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ABSTRACT: *The property valuation process uses expert knowledge combined with the sales comparison method to determine the value of a property. Automated valuation models are a fast and efficient way to carry out the process of property valuation. A study was conducted to determine if valuation mathematics used by expert valuers could be integrated into a decision support system that compensates for fluctuations in the economy. A computerised demonstrator was developed and successfully applied to test scenarios of real-world residential properties in South Africa. The expert decision support system consisted of a user interface, a decision-making module, a database of case-based properties, and a knowledge base to calculate the value of property. This paper describes the development and evaluation of the system.*

KEY WORD*: decision support systems, expert systems, property valuation, sales comparison method*

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I. INTRODUCTION

Property valuation provides an important and non-biased evaluation of a property to determine its value (Kartikasari, Karyatun, & Digdowiseiso, 2023). Such a valuation is more precise and thorough than one from the owner of the property and real estate organisations, as such governments tend to prefer the valuation of an expert. Valuations are used by real-estate organisations to gather statistics on the actual values of certain properties, while governments can use these valuations to determine property tax values (Wier, 2020). This paper focuses on the residential aspect of property valuation.

The sales comparison method is the most common valuation method for residential property valuation and involves identifying properties comparable to the subject property (the property whose value must be computed) and calculating a new value using a specific adjustment equation. In this method, it is important to note that a comparable property with the least differences in attributes such as the number of bedrooms, bathrooms, garage size, or whether the property has a swimming pool must be selected. The value of the most comparable property is adjusted according to certain methods and equations for the identified attribute differences to determine the market value of the subject property. Considering the importance of property valuation, an expert valuer must make the right decisions regarding how to select the most comparable properties and how to calculate the value of a subject property. The development of a decision support system (DSS) is proposed to assist in this process.

A DSS is a type of software program that covers many fields including economics, finance and the property and real-estate environment. The general purpose of these systems is to assist in almost any decision-making process in an organisation where the choices to be made might be somewhat abstract or depend on numerous input factors (Hendrikse, 2015). DSSs may not always generate absolute results but can be used to support certain decisions. Different types of DSSs exist and each can be used in different scenarios.

Considering that an expert valuer incorporates prior valuation knowledge and comparable property data to execute the sales comparison method, a DSS consisting of a data-driven element that stores comparable properties in a database and a knowledge-driven element that stores the necessary procedures on how to calculate a new property value, is proposed. This leads to the following question: can a DSS for property valuation in the fluctuating South African real-estate environment provide valuable decision support to an expert valuer?

This paper discusses the functionality and development considerations of the expert DSS in property valuation. To verify the system, the design science approach according to the positivistic paradigm was used to develop a computerised demonstrator for implementation in the South African property context. The system was validated according to criteria established from literature and results were evaluated using historic property valuation data.

The layout of this paper is structured as follows: section 2 contains the literature review of recent studies related to software applications in property valuation; in section 3, the methodology that was used to conduct this study is outlined; the knowledge engineering process is discussed in section 4; section 5 consists of discussions on the testing process and system validation; and the paper concludes in section 6 with a summary of the study and valuable contributions to the field.

II. LITERATURE OVERVIEW

The development of a system that can automatically calculate the value of a property using a mathematical or analytical model is known as an automated valuation model (AVM) (International Association of Assessing Officers, 2018). Such models must be tested on data sets or historic data and calibrated for optimal performance.

The method of valuing a large set of properties at once is known as mass appraisal (Bencure, Tripathi, Miyazaki, Ninsawat, & Kim, 2019). Mass appraisal requires a large data set for valuation and one of the most common techniques is known as multiple regression analysis (MRA) (Abidoye & Chan, 2016). Regression in general assists in identifying whether variables in a data set have an impact on each other and predicting their future values (Montgomery, Peck, & Vining, 2015). In property valuation, regression can provide information as to how a property's attributes influence the value of a property (Božić, Milićević, Pejić, & Marošan, 2013). However, issues such as heteroscedasticity (no recognisable patterns) and multicollinearity (an independent variable is not statistically significant) can cause the property value to be difficult to predict (Mimis, Rovolis, & Stamou, 2013; Epley, 2017; Okoruwa, 2017). To apply regression analysis, it is important to identify the correct set of property attributes (Kokot & Gnat, 2019). When gathering data for validating the regression model it is rather hard to establish property attributes without a physical inspection of each property (Bin, Gardiner, Li, & Liu, 2020). The most common method to get this information is from previous valuation reports but they are not readily available and can be very costly to obtain in South Africa, especially with large data sets (Ellenberger, Smal, & Margolius, 2010). Therefore, the identification of a selected set of attributes that have a great impact on the value of a property is ideal for an expert valuer (Kilpatrick, 2011).

Property valuation also contains a dynamic aspect that involves the date of sale. What makes this attribute interesting is the continuous fluctuations in the economy of a country. The price of a property may vary significantly every year and as such, selecting the property that has the most recent date of sale is important (Hendrikse, 2015). Expert valuers tend to limit their searches to the past 12 months of purchase, but comparable sales data might not be available in that time frame given the attributes of the property in question (Amidu, Boyd, & Agboola, 2019). As such, the value must be adjusted accordingly by using the consumer price index of that country and this varies monthly (Ellerman, 2004).

There are numerous existing DSS applications in property valuation, but many of them are focused primarily on spatial data and Geographic Information System technology (Bencure, Tripathi, Miyazaki, Ninsawat, & Kim, 2019; Bidanset, McCord, Davis, & Sunderman, 2019; Butsic, Hanak, & Valletta, 2011; Christopoulou & Haklay, 2005; Aspinall & Pearson, 2000; Christopoulou & Haklay, 2005; Demetriou, 2018). The common purpose of a geospatial DSS in property valuation is to determine how much a property is worth when a building project is to be conducted on that property. This includes the allocation of resources, the building of certain equipment (like a borehole) or the occupation of land, to name a few (Bencure, Tripathi, Miyazaki, Ninsawat, & Kim, 2019; Bidanset, McCord, Davis, & Sunderman, 2019). A DSS in such a case would assist in determining the type and location of the equipment to maximise the property value. This type of property valuation focuses primarily on the 'vacant stand' type of property that is only an open piece of land. Another application of a DSS is seen in the study by Lam, et al. (2009) in which a decision element was used to select the appropriate property attributes by using a weighted system to give each variable a certain 'weight' of importance. This system, however, does not select comparable properties and only relies on selecting attributes to consider when searching for properties.

III. RESEARCH METHOD

It is important to follow a certain method when conducting research to obtain comprehensive insight into the specific research field. Therefore, research is conducted according to a particular methodology (Rehman & Alharthi, 2016). In this particular property valuation scenario, a practical research approach needed to be followed (Amidu, Boyd, & Agboola, 2019). This study was conducted according to the positivistic paradigm which defines research as studying how a field or environment functions and identifying the rules that govern it (Randolph, 2019). Positivism usually revolves around formulating a problem statement, conducting experiments, and testing whether the results of the experiment solve a problem or at least provide insight as to how a field can be improved upon (Feigl, 2020). Research in this paradigm is conducted according to the design science method, where certain theories or problems are resolved by designing or simulating a solution through experimentation (Rehman & Alharthi, 2016). This study involved the development of an experimental DSS and verified whether this type of technology was applicable in dynamic residential property valuation in South Africa. Considering the full-cycle involvement of expert valuers during design and to ensure system integrity, the expert system development lifecycle was used to develop the DSS.

The data collection process involved studying existing knowledge in the field. The best way to gain knowledge is through experiencing property valuation in practice. Knowledge engineering, therefore, involved interviewing experts in the field and analysing prior research studies.

IV. KNOWLEDGE ENGINEERING

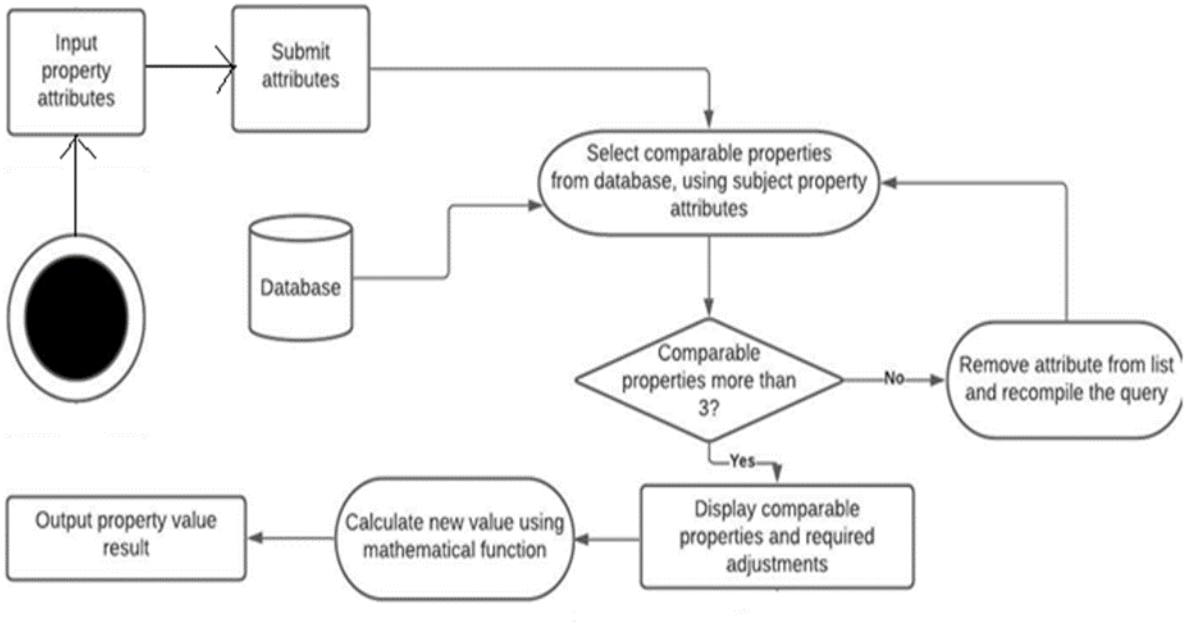
The approach to property valuation is influenced by economic, environmental, political and many more factors and, therefore, differs around the world (Abidoye & Chan, 2016). The study reported on in this paper was conducted in South Africa and applies to the residential property environment. Prior research in property valuation in South Africa is limited, therefore, the knowledge of expert valuers was invaluable. The first step was to identify which section of residential property valuation can be improved upon by a DSS tool.

4.1. The applicable valuation section

Interviews have been conducted with three different expert valuers to determine how the valuation process is executed and how a system can be implemented to assist in the resulting valuation process. The experts agreed that in the sales comparison method, an abstract and rather unscientific decision-making approach is generally followed to select comparable properties for use in valuations.

The sales comparison method was supplemented by a DSS, validated by experts in the field and literature. The valuation process, conducted by the DSS, is illustrated in Figure 1.

Figure 1: Task flow of the DSS



The developed DSS selects the property with the least attribute differences from the subject property. It then uses a mathematical model to calculate the value of a new (subject) property after comparable properties have been selected. This is discussed next.

4.2. The sales comparison model

The value of a property is calculated as the sum of the selling price of the selected comparable property and the adjustments that must be made for differences in attributes. The general mathematical equation to calculate the market value (z) of a new property is expressed as

$$z = p + \sum_{i=1}^{m} x_i \qquad (1)$$

where p represents the sale price of the selected comparable property, x_i is the value adjustment for the i^{th} attribute and m is the number of attributes to be adjusted for. This model adjusts for attributes that have direct price values associated with them retrieved from a lookup table in the property database, for example, a single garage as opposed to a double garage. There are, however, other attributes that do not have direct price values associated with them, meaning that the adjustment must be carried out through different means. The most common method to adjust these variables is to assign a certain value or coefficient to them according to a specific approach. Such adjustments are incorporated into the valuation equation as follows:

$$z_a = \prod_{j=1}^{n} y_i \left(p + \sum_{i=1}^{m} x_i \right) \quad (2)$$

$$y_i = \frac{s_i}{c_i} \quad (3)$$

where n denotes the number of attributes that must be adjusted for, s_j is the coefficient of the j^{th} attribute for the subject property, and c_j is the coefficient of the j^{th} attribute of the comparable property. The quotient of s_j and c_j is an indication of the adjustment(s) made which cannot be directly subtracted or added to the property value while still influencing the value of the property. These attributes, denoted by y_i are known as indirect attributes.

The higher the number of attributes considered, the more accurate the valuation will be, but this is subject to limited availability because very few sources provide detailed descriptions of properties demanding physical property inspections. According to the South African Valuer's Council, the attributes in Table 1 have been identified to be the most important in the sales comparison method. The direct attributes are property attribute assessment values that are directly subtracted or added to the value of the most comparable property, while the indirect attributes are represented by multipliers to adjust the value of the property after the direct adjustments have been completed.

Table 1: Residential property attributes to be used in this study

Direct Attributes (x_i)		
Name of attribute	Description	Example Value
Garages	The number of garages that the property has.	Single: R50000, double: R85000
Flat	Whether the property has a flat and the size of the flat.	Single flat: R150000
Number of bedrooms	The number of bedrooms that a property has.	Cost per extra bedroom: R100000
Number of bathrooms	The number of bathrooms that a property has.	Cost per extra bathroom: R45000
Domestic quarters	The description of whether the property has domestic quarters.	If domestic quarters are not present, subtract the property value with R50000
Amenities	Any additional features contained within the property, such as a swimming pool.	A pool: R100000
Indirect Attributes (y_j)		
Name of attribute	Description	Example Value
Property condition	The overall condition of the property.	If the property is in good condition, multiply with a value of 1. If it requires structural maintenance, multiply with a value of 0,80
Date of sale	The date that the property was sold or valued previously.	Each month has a certain consumer price index (CPI) value. For instance, in February 2020, South Africa had a CPI of 115,2, while in July the CPI was 116,4
Average suburb value	The average value of properties that are situated in the suburb of the subject property or the comparable property.	The average value of the subject property's suburb, for example, *Doringkruin*, is R1098500, while the comparable property's suburb of *La Hoff* is R888200.

When a specific direct attribute must be adjusted for, an attribute adjustment value is assigned to that attribute in the equation. For example, a property with a single garage amounting to R50000 which is compared to a property with a double garage amounting to R85000, will result in an adjustment of -R35000. If no adjustment is needed for that direct attribute, the coefficient for that attribute is zero and no adjustment is made. The direct attributes (x_i) are represented as fixed cost values and the indirect attributes (y_j) act as multipliers.

The model used for valuation needs to be further modified when the date of sale of the comparable property is older than 12 months. While valuers attempt to select recently sold properties, alternative adjustments are required when none is available. To calculate how the value must be adjusted, the valuer uses the current consumer price index (CPI) of a country and compares it to the CPI at the time of sale of the comparable property (Hendrikse, 2015). The CPI measures the change in the price of goods and services in a country and is readily available through online resources.

In the sales comparison method, properties that are located within one kilometre of each other are compared but sometimes none are available in that range. The value adjustment is then calculated as the average value of properties in the neighbourhood of the subject property divided by the average value of properties in the neighbourhood of the comparable property. The condition of the property is adjusted for in much the same manner.

4.3. The decision-making module

The data-driven component of the DSS selects comparable properties from a property database. For this study, the database contains a data set of 103 properties selected from the town of Klerksdorp in the Northwest province of South Africa and the required data were obtained from the National Deeds Office.

The system starts by retrieving properties from the database that share the same attributes as the subject property. The property with the least number of required adjustments to be made is selected. The knowledge-driven component determines how the attributes should be adjusted according to the models formulated and their applicable constraints. Finally, the estimated market value of the subject property is calculated.

V. RESULTS

The expert valuers identified in the study first assisted in verifying whether the system executed the valuation process correctly. The DSS was developed to display each step of the valuation process for complete transparency. The expert valuers were able to identify when the system was executing its tasks incorrectly, result assessments. Alterations proposed by the experts were implemented after which system validation commenced.

The best way to validate the system is to compare the output generated to existing and recent valuations. The system was tested against 22 historic valuations, half of which was provided by the interviewed experts and the other half was collected from the Municipal Valuation Roll of the Klerksdorp area in the Northwest province of South Africa. The expert valuers implemented the sales comparison method on their valuations, while the Municipal Valuation Roll implemented an automated mass-appraisal technique for their valuations. There are 11 suburbs in the town of Klerksdorp.

The Pearson correlation coefficient was calculated to establish the correlation between valuations of the expert valuers, and the DSS created in this study (Swanepoel, Swanepoel, Van Graan, Allison, & Santana, 2011). The Pearson correlation coefficient can be calculated as follows:

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}} \quad (3)$$

where, for the DSS, x is the values of the i^{th} property and $\bar{x}$ its average; for the Municipal Valuation Roll and the expert valuers, y represents the values of the i^{th} property and $\bar{y}$ its average; and n the number of properties that were valued. Tables 2 and 3 present the results of the valuations produced by the system compared to the historic valuations.

Table 2: Valuation results from the system compared to the Municipal Valuation Roll

Valuation results from the Municipal Valuation Roll				
Property number	**Suburb**	**Valuation Roll valuation (R)**	**Valuation produced by DSS (R)**	**Correlation**
M1	Flamwood	1200000	2119684	0,57
M2	Roosheuwel	620000	644028,8	0,96
M3	Doringkruin	1060000	1300879	0,81
M4	Flimieda	850000	860154,4	0,99

M5	Meiringspark	720000	633888,9	0,88
M6	Adamayview	620000	608600,2	0,98
M7	Ellaton	640000	492001	0,77
M8	Elandsheuwel	720000	847329,3	0,85
M9	Wilkoppies	1750000	4024692	0,43
M10	Neserhof	780000	789073,3	0,99
M11	La Hoff	780000	714428,7	0,92
Correlation (r)	0,98			

The correlation between the two sets of valuations in Table 2 is 0,98, proving a very strong positive association between them.

Table 3: Valuation results from the system compared to the expert valuers

Valuation results from the expert valuers				
Property identifying value	**Suburb**	**Valuation from expert valuer (R)**	**Valuation produced by DSS (R)**	**Correlation**
E1	Elandsheuwel	1235000	1124812	0,91
E2	Wilkoppies	2200000	2175225	0,99
E3	Roosheuwel	500000	521956,1	0,96
E4	La Hoff	1350000	1116243	0,83
E5	Doringkruin	1300000	1241297	0,95
E6	Meiringspark	600000	812986,9	0,74
E7	Neserhof	710000	633482,1	0,89
E8	Adamayview	320000	616049,2	0,52
E9	Flamwood	1450000	1400000	0,97
E10	Flimieda	1200000	1000000	0,83
E11	Ellaton	460000	472500	0,97
Correlation result (r)	0,96			

Correlation between the valuations from the Municipal Valuation Roll and the DSS in Table 3 averaged at 0,96. The correlation values show that the DSS provides good, automated valuation results. Properties M1, M9 and E8, however, show a major difference in correlation and are discussed later.

In most of the valuations generated, the system had to compensate for the date of sale because many of the comparable properties from the database were sold before the year 2020. Table 4 shows the correlation of valuations produced by the DSS compared to properties sold more than 12 months earlier.

Table 4: Valuations of properties that were compared with newer properties during calculation

Property number	**Suburb**	**Date of valuation**	**Date of sale of most comparable property**	**Correlation**
E7	Neserhof	02/24/2014	05/23/2019	0,89

E3	Roosheuwel	06/04/2015	030/7/2019	0,96
E6	Meiringspark	01/14/2016	04/10/2018	0,74

The system prioritises the selection of comparable properties from the same suburb as the subject property but sometimes that property does not represent the average value of the suburb accurately, for example overpriced or under-valuated properties. Examples of this phenomenon are shown in Table 5, where the DSS calculated higher values for subject properties as opposed to expert valuers or the Municipal Valuation Roll.

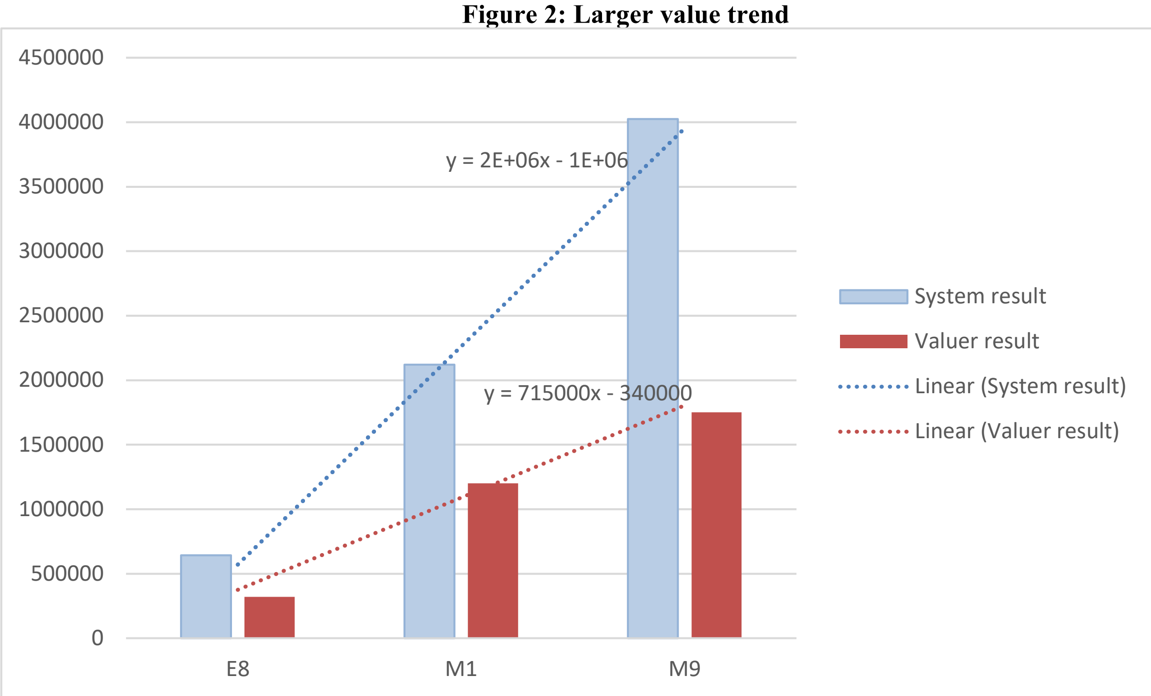
Table 5: Calculated value of property using a comparable property with a larger value

Property number	Suburb	The value produced by the expert valuer or Valuer's Roll (R)	DSS generated price (R)	Correlation
E8	Adamayview	320000	642000	0,52
M1	Flamwood	1200000	2119684	0,57
M9	Wilkoppies	1750000	4024692	0,43

The DSS does not compensate for the difference in property values for one suburb. This means that even though the average suburb value can give a good indication of how much a property is worth in that suburb, certain comparable properties might misrepresent the average property values of a suburb.

Property E8 in Table 5, for example, is one for which the DSS compared the subject property with a property that accurately represented the average suburb price, but the expert valuer compared it to a property that was sold for much less than the average suburb value. The correlation between the values generated by the DSS and estimated by the expert valuer for properties M1 and M8 is low because the comparable properties selected by the valuer misrepresented the average value for the suburb. The reasoning behind this is that in the data set, the suburbs of Flamwood and Wilkoppies contain many overpriced and underpriced properties when compared to average prices in those suburbs. This trend is shown in Figure 2.

Figure 2: Larger value trend



This illustrates one of the main limitations of the system. It is dependent on the property data that is associated with it. If any properties with abnormally large or small values are present that do not correctly represent a proper representation of attributes, the system calculates an inaccurate value for a property.

VI. DISCUSSION

System validation revealed that the developed DSS offers substantial decision support by providing expert valuers with statistically significant valuation results. Apart from some exceptions, a high correlation was observed between valuations generated by the DSS and those produced by expert valuers, and even more so with the Municipal Valuation Roll. The DSS incorporated a combinatorial method towards valuing a property, resulting in the assumption that it can be an alternative, but valid mass-appraisal technique. This higher accuracy is because expert valuers adapt their property selection and adjustment techniques, depending on the property being valued, while the DSS uses standard calculation and adjustment techniques. Expert valuers also incorporate a more hands-on approach towards calculating their valuation results (Amidu, Boyd, & Agboola, 2019), where the DSS can provide excellent decision support. Heteroscedasticity and multicollinearity do not affect the DSS because pattern recognition in the data set is not utilised.

The DSS attempts to compensate for a fluctuating property market by adjusting the property value according to the consumer price index of a certain time. The results have shown certain properties that moderately accurate valuations are generated when it uses comparable properties with dates of sale differing considerably, with correlation ranging from 0,74 to 0,96.

This incorporation of the DSS is highly dependent on the availability of any data set of comparable properties and adjustment values. Sometimes the properties used for comparison, are unique and were sold for irregular prices when considering their attributes, leading to system inconsistencies. A possible way to counteract this is to use an error value that is derived from the dataset of comparable properties associated with the current system, but such modifications can have new complications.

The biggest limitations of the DSS are data dependence and availability. Data dependence means that the system will not be applicable for valuations in other towns or cities, even other countries if property data from those areas are not available. Availability is a problem because data sets that can provide more in-depth descriptions of property attributes are limited.

This study contributes to the field of property valuation by providing expert valuers with a statistically significant second opinion when valuing properties. Practice in property valuation is an important learning tool (Amidu & Boyd, Expert problem solving practice in commercial property valuation: an exploratory study, 2018)and the DSS can provide valuable decision support in this area as well. The incorporation of a DSS for residential valuations is not limited to this study. A few possible recommendations are to find new models for property value calculation in the scope of a DSS for property selection. Other ideas include incorporating a DSS to assist in property tax estimations, and expanding the system to other areas if data are available.

VII. CONCLUSION

Property valuation requires proper methods or tools to assist in the valuation process, either to automate the process or to aid when the valuer is unsure of how to select comparable properties. This paper contains a detailed discussion on the development of a DSS to assist in conducting the valuation process of residential properties in the South African real estate environment.

The study started by identifying existing automated valuation techniques and identified related research of DSS technology in the valuation domain. Afterwards, data collection techniques were discussed, along with how a DSS was to be incorporated into the property valuation domain for residential properties. With the valuation method established, a demonstrative version of the system was developed and tested on historic valuations to validate its accuracy.

The DSS produced statistically significant results that highly correlated with the historic valuations, save for some exceptions. The DSS compensates for some of the limitations of mass-appraisal techniques. Validation proved that the DSS can be implemented to assist in the residential property valuation process, given that the data set it works with applies to a specific region, such as a town or a city. The system can be expanded and tested on different regions or even on an international scale.

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