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# Research Trend of the Application of Artificial Neural Network in Property Valuation

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## Abstract

The Artificial Neural Network (ANN) technique has been applied and found useful for solving forecasting problems in different property markets around the world. However, the trend of ANN's application in property valuation research has been undocumented. Therefore, this study aims to systematically review the extant literature on the application of ANN to property valuation. The analysis of the retrieved articles revealed that a seminal study in this area was reported in 1991. To date, the technique has continued to gain popularity amongst real estate researchers. Most of the reviewed articles originated from developed countries, particularly the US and the UK, although a few studies emanated from emerging economies. Most of the authors that contributed to the publications are affiliated to university faculties and most of the studies found ANN to have outperformed other appraisal techniques, in terms of accuracy. The gaps identified in this study need to be addressed in order to achieve sustained growth in property appraisal practice on a global scale.

**Keywords:** Artificial Neural Network, real estate, property market, property valuation, review

## 1 Introduction

In arriving at the value of a property, valuers/appraisers normally adopt one or more valuation techniques. These approaches, especially the traditional ones, have been proven to be inadequate in producing objective valuation figures (Zurada et al 2006). For instance, the hedonic pricing model (HPM) that has been widely adopted in real estate valuation research (Bender et al 2000), and even in practice (McCluskey et al 1997), cannot capture the underlying nonlinear relationship that exists between property value and property attributes (Do & Grudnitski 1992). Hence, the estimation of inaccurate and unreliable valuation figures. Reliable and accurate prediction of property value is of valuable interest to real estate stakeholders for one important reason: investment decisions are based on estimated valuation figures. In pursuit of a reliable and accurate valuation estimation, researchers have adopted artificial intelligence (AI) into property valuation in order to improve the accuracy of valuation estimates, and one of such AI technique is the artificial neural network (ANN) technique.

ANN is an AI technique programmed to function like the human neural network. ANN has a learning ability just like the human brain neurons. It has been adopted in different fields of studies for prediction, pattern recognition, forecasting, classification and nonlinear mapping, among others (Cechin et al 2000; Paliwal & Kumar 2009), and has produced outstanding reliable results (Paliwal & Kumar 2009). The technique was introduced to the real estate research domain in the early 1990s and till now scholars in different real estate markets around the world continue to adopt the ANN technique in property price forecasting. Scholars (Pagourtzi et al 2003; Limsombunchai et al 2004; Guan et al 2008, amongst others) have reported its outstanding performance in property valuation and even over other AI techniques, such as the fuzzy logic system (FLS), Autoregressive Integrated Moving Average (ARIMA) and spatial analysis. Despite its wide embrace by real estate scholars, the extent of the application of ANN in property valuation research remains unknown. Therefore, this study is aimed at

systematically reviewing published studies focused on the application of ANN to property valuation. The findings of the proposed research will highlight the current situation and identify the gaps in this research area. This present study will reveal the active researchers in this field, their affiliations, the countries of origins of these articles, the annual trend of the publication output and a summary of the research findings of these studies.

## **2 Artificial neural network: A brief history**

The history of the ANN technique can be categorized into four stages namely beginning of neural networks – the 1940s; the first golden age – the 1950s to 1960s; the quiet years – the 1970s; and the renewed enthusiasm period of the 1980s – now (Yadav et al 2015). The final stage is the present day neural network research area where the application of the technique exploded and received more attention by scholars. The study of McCulloch & Pitts (1943) was the first to employ the ANN technique to demonstrate the ‘threshold logic’ in the field of mathematics. Thereafter, the technique has been adopted successfully in different fields of studies (Zhang et al 1998). These areas of research include but are not limited to, health (Wesolowski & Suchacz 2012), engineering (Yuan & Guangchen 2011), marketing (Chiang et al 2006), the stock market (Eriki & Udegbumam 2013), and tourism demand (Burger et al 2001), amongst others.

In the real estate domain, the seminal study of Borst (1991) was the first to apply the ANN technique to property appraisal. The author found that ANN is reliable and accurate for property value estimation, but recommended that more research efforts be invested in the application of ANN. Since it has been established that the ANN technique handles the shortcomings of most of other appraisal techniques (Do & Grudnitski 1992), researchers in different real estate markets around the world have investigated its application in their domains and have mostly reported a positive result (Limsombunchai et al 2004). The trend of these articles is reported in the present study.

## **3 Research method**

In order to achieve the objectives of this study, a systematic literature review was adopted. This is to ensure that both the current state of knowledge and also the research gaps are identified from the existing literature (Mayer 2009), and also to identify the major scientific contributions to the subject under investigation (Tranfield et al 2003). By adopting this approach, references will be made to previous studies in justifying assertions, making comparison and drawing inferences (Denscombe 2014). Therefore, articles that have utilized the ANN technique solely or in comparison with other appraisal techniques in property valuation research were retrieved from online databases and search engines such as ScienceDirect, Taylor & Francis, Springer and Google Scholar. Studies that adopted its hybrid application with other AI techniques, for instance, Liu et al (2006); Guan et al (2008), amongst others, were excluded from the search. This approach is similar to that adopted by Yi & Chan (2013), in reviewing labor productivity research in construction journals.

The search started with the input of the following search words into the databases and search engines artificial neural network, property price prediction, artificial neural network in property appraisal, real estate price forecasting, artificial intelligence property appraisal, multilayer perception, real estate price modeling, multilayer perception in property price forecasting, modeling property price and mass real estate appraisal. The obtained articles were scrutinized in order to ensure that only articles that met the inclusion criteria were eventually retrieved. However, only studies published in the form of journal articles, conference proceedings and book sections were found to be relevant for the present study, hence, these are the types of articles reviewed. It is worth mentioning that in a situation where the same research finding was published in a journal as well as a conference proceeding, the one published in the journal was chosen. For instance, the study of Limsombunchai (2004) and Limsombunchai et al (2004), are the conference proceeding and journal article, respectively.

At the end of the search exercise, 52 articles were eventually retrieved. These articles were subjected to analysis and the findings were presented using descriptive statistics to establish the active authors of the articles, the affiliations of the authors, the number of research papers published annually, the origins of these publications (i.e. the study area), the collaborations that exists amongst researchers and the publication outlets of the articles.

## 4 Results and discussion

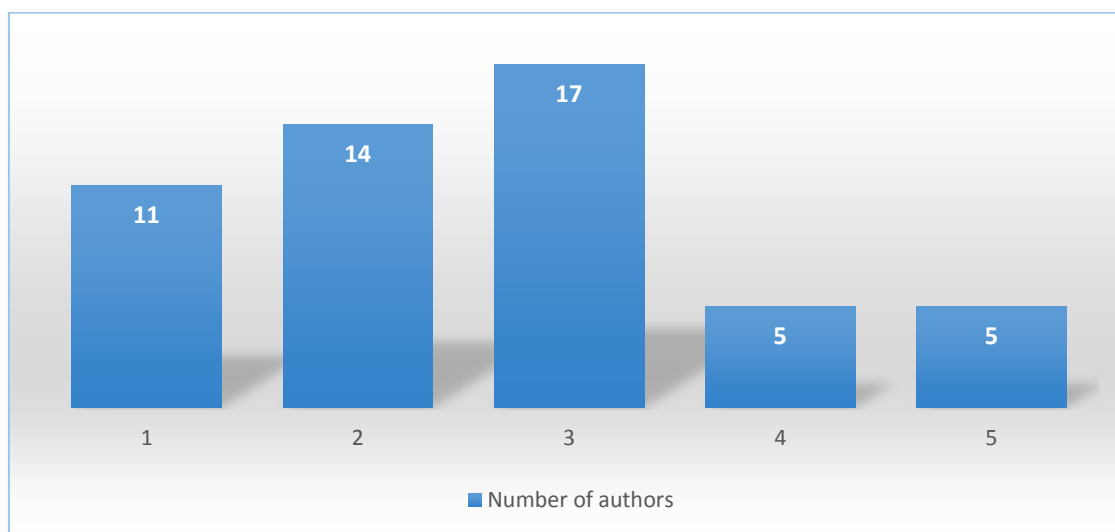
### 4.1 Active authors

Considering the turnout of publications by numerous scholars, a total of 135 authors contributed to the publication of the reviewed articles. It is evident that most of those authors have published at most one article during the study period, although some have published more than one article. The details of authors that have published at least two articles are presented in Table 1. McCluskey, W. and Jenkins, D. H. are the highest contributors to this research topic, with four articles each to their credit. In the same vein, Borst, R. A. and Ware, J. A. have published three articles each. These scholars can safely be referred to as active contributors to this research area.

**Table 1** Active contributors of publications

Authors	Studies	No. of publications
McCluskey, W.	McCluskey (1996), McCluskey & Borst (1997) McCluskey et al (2012); McCluskey et al (2013)	4
Jenkins, D. H.	Lewis et al (1997); Jenkins et al (1999); Panayiotou et al (2000); Wilson et al (2002)	4
Borst, R. A.	Borst (1991); Borst (1995); McCluskey & Borst (1997)	3
Ware, J. A.	Lewis et al (1997); Jenkins et al (1999); Wilson et al (2002)	3
Worzala, E. M.	Worzala et al (1995); Lenk et al (1997)	2
Lenk, M. M.	Worzala et al (1995); Lenk et al (1997)	2
Lewis, O. M.	Lewis et al (1997); Jenkins et al (1999)	2
Rossini, P.	Rossini (1997); Rossini (1998)	2
Levitan, A. S.	Zurada et al (2006); Zurada et al (2011)	2
Zurada, J. M.	Zurada et al (2006); Zurada et al (2011)	2
Guan, J.	Zurada et al (2006); Zurada et al (2011)	2
McCord, M.	McCluskey et al (2012); McCluskey et al (2013)	2
Kauko, T.	Kauko et al (2002); Kauko (2003)	2
Haran, M.	McCluskey et al (2012); McCluskey et al (2013)	2
Davis, P. T.	McCluskey et al (2012); McCluskey et al (2013)	2
McIhattan, D.	McCluskey et al (2012); McCluskey et al (2013)	2

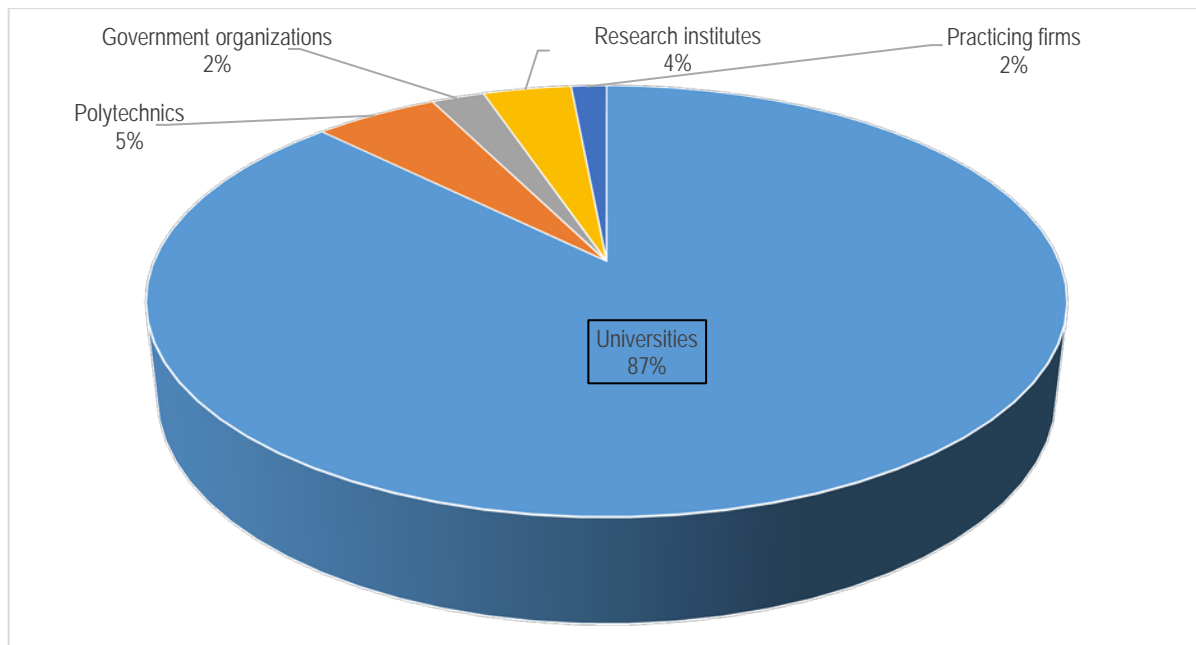
From the analysis of the articles, it can be established that researchers have been collaborating in this study area. This is evident from 41 (79%) out of the 52 reviewed articles having been co-authored by at least two people, with the maximum number of authors being five (see Figure 1), whereas only 11 (21%) were sole-authored. The mean number of authors is 2.9, which indicates that most of the papers were authored by three scholars. It can be suggested that for outstanding results to be achieved in this research endeavor, collaboration should not be overlooked by researchers.



**Figure 1** Authors' collaborations

#### 4.2 Affiliations of the authors

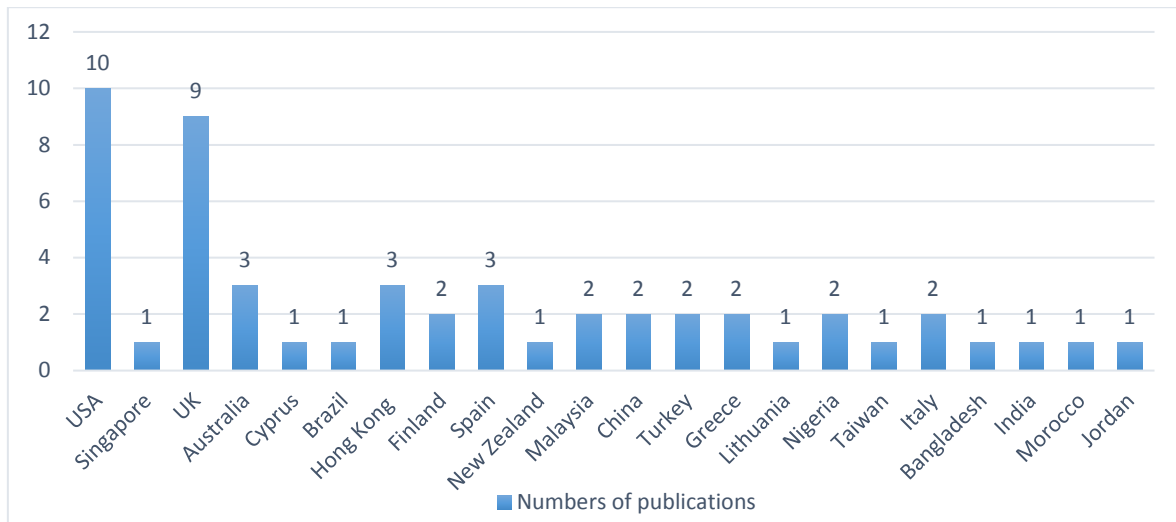
The analysis of the articles shows that the authors were either affiliated to a university, polytechnic, research institute, government organization or practicing firm. However, the statistics presented in Figure 2 reveals that 87% (118) of the authors were affiliated to a university, 5% were affiliated to a polytechnic, 4% researchers were domiciled in research institutes, while 2% were affiliated to government organizations and practicing firms, respectively. This corroborates previous related studies (Adewunmi & Olaleye 2011; Holt et al 2015; Utama et al 2016) that found that researchers domiciled in universities are the highest contributors to real estate and built environment research. Research is essential for providing a body of knowledge for a particular discipline (Hemsley-Brown & Sharp 2003), so it is imperative that industry based real estate professionals should be actively involved in research in order to achieve a sustainable real estate practice.



**Figure 2** Authors' affiliations

#### 4.3 Origin of the publications

The reviewed articles were conducted in different real estate markets of the world. Figure 3 shows that all the articles emanated from 22 countries in the world. Of these 22 nations, one article each was published in almost half (10) of the countries. The highest number of publications originated from the United States, where about 20% of the total number of publications reviewed were conducted. This is also the case in the United Kingdom, from where 17% of the articles reviewed emanated. It can be concluded that most of the articles published in this research area emanated from developed countries. This can be substantiated with the next highest number of publications of three articles each originating from Australia, Hong Kong and Spain, respectively. Some studies were conducted in a few developing countries, with mostly one article to their credit. The low adoption of the ANN technique in these emerging property markets may be attributed to a lack of know-how in its application for property valuation in these developing countries (Abidoye & Chan 2016). And as noted in the present study that collaboration between scholars in this research area has brought about many results, researchers domiciled in developing countries could explore the possibility of collaborating with established scholars in developed countries. This could result in a global exposition of researchers in developing countries to AI appraisal techniques.



**Figure 3** Origin of publications

#### 4.4 Annual trend of research output

The first application of ANN to property valuation was reported in 1991 (see Borst 1991). Subsequently, various scholars from different parts of the world have applied ANN to property valuation research. This is also the case in the finance research area where the ANN technique was first adopted at the beginning of the early 1990s (Ramos & Martínez 2013). Figure 4 shows the annual trend of research output from 1991 to 2015. From Figure 4, it is clear that there has been fluctuations in the number of articles published between 1991 and 2015. In most years, mostly one and two publications were recorded with the exception of 1997 and 2011 where four and six articles were published, respectively. On a decade basis, 16 articles were published in the first decade (1991-2000) of the introduction of ANN to real estate appraisal. This figure rose to 20 between 2001-2010, probably due to its rapid popularity amongst real estate researchers (Adhikari & Agrawal 2013). In the present decade (2011- 2020) of the life cycle of the technique in the real estate domain, 16 articles have been published so far in just five years into the decade. Taken together, since 2011 when the highest number of publications was recorded, there has been a drastic drop in the annual publication output which has been fluctuating between two and three annually. It is expected that the number of publications should increase yearly since not all the real estate markets of the world have been modeled using the ANN technique. Continuous effort is needed to be invested in automating property valuation globally, and the exploration of the adoption of AI techniques such as the ANN technique should therefore, be sustained.

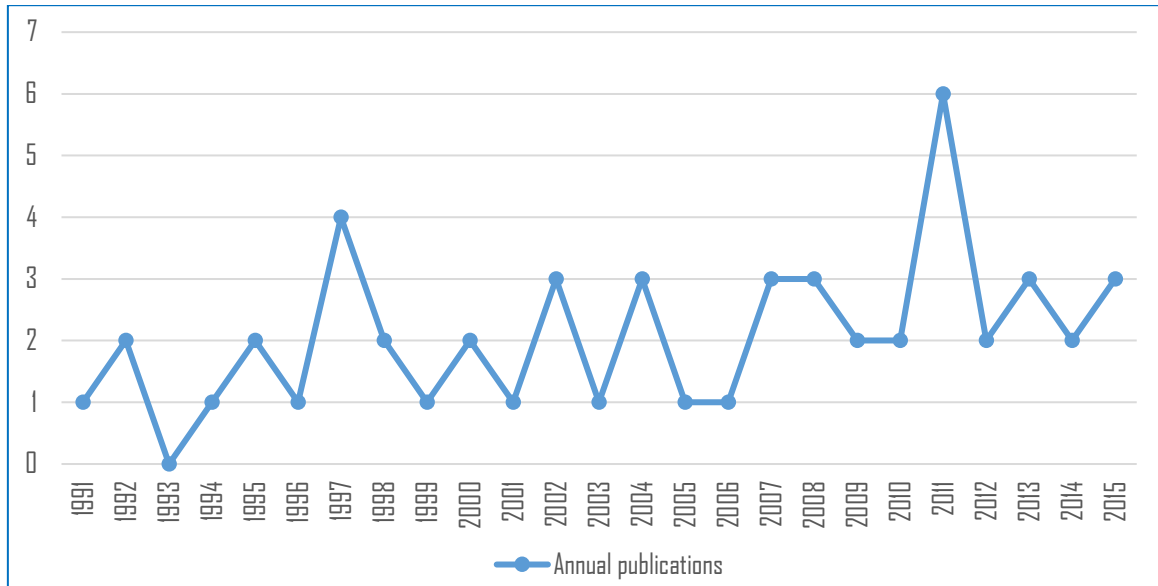


Figure 4 Annual output of publications

4.5 Publication outlets

From the analysis of the reviewed articles, 43 articles were published in different journal outlets, eight were proceedings from international conferences, while one is a book section. Most of the journal outlets have published just one article over the study period, whereas some have published more than one article. Table 2 shows the journals that have published more than one article since 1991 to 2015. Four articles each have been published in the Journal of Real Estate Research and Journal of Property Research, while three were published in the Journal of Property Valuation and Investment. This indicates that research outputs are likely to be published in these outlets.

Table 2 Popular journal outlets

Name of journal	No. of publications
Journal of Real Estate Research	4
Journal of Property Research	4
Journal of Property Valuation and Investment	3

4.6 Summary of research findings

The findings of each article was analyzed in terms of the performance of the ANN technique in property valuation. This was examined in order to establish 1) if the performance of the ANN technique is better than other approaches, 2) if the performance of ANN is at par with other techniques, and 3) if other appraisal techniques perform better than the ANN technique. In about 82% of the articles reviewed, the ANN technique was reported to perform better than other techniques. In 11% of the cases, the performance of ANN was equal to that of other valuation approaches, while 7% of the studies reported that the ANN technique did not outperform other valuation techniques. This corroborates the finding of previous similar studies (Paliwal & Kumar 2009) where in most of the articles reviewed, the outstanding performance of the ANN technique over other methods was confirmed. Despite the superior predictive performance of ANN models reported in property valuation research, the technique is classified as a ‘black-box’ model (McGreal et al 1998; Lam et al 2008), implying that it is difficult to explain what goes on in the hidden layer of the model. However, the recent development of techniques such as sensitivity analysis (Cortez 2010) have proven that the internal workings of AI models can be understood. A sensitivity analysis of AI models (such as ANN) has been proven to be particularly useful in past studies found in the literature (Cortez et al 2009; Tinoco et al 2011).



## 5 Conclusion

A review of the studies that adopted the ANN technique for property valuation was documented in this study. Articles that were retrieved from online databases and search engines were analyzed in order to present the history and trend in the research area. The technique was first introduced into the real estate appraisal domain in 1991 and since then, it has been gaining greater acceptance by real estate scholars. It was found that majority of the publications reviewed were conducted by real estate scholars domiciled in university faculties, while, real estate professionals practicing in other organizations have contributed little to the research debate. Similarly, most of the articles were conducted in developed countries, with few emanating from developing countries. The low usage of this technique in developing economies could be due to the lack of the knowledge in the application of the ANN technique, unavailability of a rich database of property sale transactions and/or concerns regarding the reliability of available data. There is a need for real estate researchers and professionals in emerging property markets to collaborate with their counterparts in the developed world to bridge this gap in knowledge. Over the study period (1991-2015), annual research output fluctuated. However, the highest annual publication was recorded in 2011, with the annual output declining since then. It will be interesting to investigate the reason(s) for this decline, probably there has been a paradigm shift to other contemporary appraisal technique(s). In most of the studies reviewed, the outstanding predictive and forecasting ability of the ANN technique was established, which corroborates the existing literature. However, it must be noted that this does not suggest that application of ANN will address all real-world valuation problems. This is because there is a need for expert experience during the process of model development (for example the selection of input variables). Also, valuation techniques are embedded with various degrees of strengths and weaknesses.

Due to the successes recorded in this research area in different parts of the world during the study period, there is a need for conscious effort to propagate its exploration in other real estate markets that have not been optimally explored. When this is achieved, in theory, it could be easier to introduce it to the real estate appraisal practice and that could lead to a sustainable global real estate practice. This study cannot be said to be exhaustive based on the number of articles reviewed, as articles not indexed in the databases searched might have been omitted. Also, the choice of the search words might not have captured some relevant studies that do not have these words in their titles, keywords or abstracts. However, the retrieved articles were subjected to a systematic analysis, so as to draw useful inferences from the pool of publications. In filling the gap of the low application of ANN in developing countries, effort will be made in future research in modeling the Nigerian real estate market, its being an emerging real estate market and the biggest economy in Africa.

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