Artificial Neural Network in Property Valuation: Application Framework and Research Trend

Rotimi Boluwatife Abidoye[1*] and Albert P. C. Chan[1]
[1]*Department of Building and Real Estate, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong*

*Corresponding author's Email: rotimi.abidoye@connect.polyu.hk

Abstract

Purpose - The predictive accuracy and reliability of artificial intelligence models, such as the Artificial Neural Network (ANN), has led to its application in property valuation studies. However, a large percentage of such previous studies have focused on the property markets in developed economies and at the same time, effort has not been put into documenting its research trend in the real estate domain. This study nonetheless, critically reviews studies that adopted ANN for property valuation in order to present an application guide for researchers and practitioners and also establish the trend in this research area.

Design/methodology/approach – Relevant articles were retrieved from online databases and search engines and were systematically analysed. Firstly, the background, the construction and the strengths and weaknesses of the technique were highlighted. In addition, the trend in this research area was established in terms of the country of origin of the articles, the year of publication, the affiliations of the authors, the sample size of the data, the number of the variables used to develop the models, the training and testing ratio, the model architecture and the software used to develop the models.

Findings - The analysis of the retrieved articles shows that the first study that applied ANN to property valuation was published in 1991. Thereafter, the technique received more attention from 2000. While a quarter of the articles reviewed emanated from the United States, the rest were conducted in mostly developed countries. Most of the studies were conducted by universities scholars, while very few industry practitioners participated in the researches. Also the accurate predictive ability of the ANN technique was reported in most of the papers reviewed, although a few reported otherwise.

Research limitation - Articles that are not indexed in the search engines and databases searched and also not available in the public domain might not have been captured in this study.

Practical implications – The findings of this study reveals a gap between the valuation practice in developed and developing property markets and also the contributions of real estate practitioners and universities scholars to real estate research. A paradigm shift in the valuation

practice in developing nations could lead to achieving a sustainable international valuation practice.

Originality/value – This paper presents the trend in this research area that could be useful to real estate researchers and practitioners in different property markets around the world. The findings of this study could also encourage collaboration between industry professionals and researchers domiciled in both developed and developing countries.

Keyword: artificial neural network; property valuation; property market; developing countries; developed countries, review.

Paper type: General Review

1. Introduction

The accuracy and reliability of property value estimates is an issue of great importance to real estate stakeholders. For instance, Taffese (2007) pointed out that financial and economic decisions are based on property valuation estimates reported by property valuers. Empirical evidence from previous studies has shown that traditional valuation techniques tend to produce inaccurate estimates, are subjective in nature and are unreliable (Bagnoli and Smith, 1998; Taffese, 2006; Paris, 2008). Moreover, Jiang et al. (2013) argued that the global economic meltdown experienced between 2007 and 2009 may be attributed to the adoption of unreliable valuation approaches in the mortgage process, amongst other problems. Hence, the need for the identification and adoption of a more accurate property valuation technique is crucial (Waziri, 2010).

The advent of the computer technology has led to the introduction of Artificial Intelligence (AI) modeling techniques which include the Artificial Neural Network (ANN) technique which is designed to mimic the human brain (Mora-Esperanza, 2004). The ANN model has been used for prediction, pattern recognition, classification, process control, non-linear mapping and data analysis (Cechin et al., 2000; Paliwal and Kumar, 2009), which thus makes it suitable for property appraisal (Elhag, 2002). The ANN model has been successfully applied in different property markets around the world and has produced more accurate and reliable estimates with greater speed (Ge, 2004).

With the various published results of the applications of the ANN model in the real estate research domain (Limsombunchai et al., 2004), no effort has been invested in presenting the research trend of this research topic. In addition, most of its exploration and application in the real estate domain have emanated from developed economies (see for instance, Do and Grudnitski, 1992; Tay and Ho, 1992; Lam et al., 2008; Selim, 2009; McCluskey et al., 2013, amongst others). Whereas, the ANN technique has not received much attention in the real estate domain in developing countries (Mooya, 2015; Abidoye and Chan, 2016). However, due to the demand for sophisticated property appraisal service by real estate stakeholders in this technological age (Taffese, 2006), it is imperative for real estate researchers and practitioners in different real estate markets around the world to be acquainted with the AI appraisal techniques (Yalpir, 2014). At the same time, there is a need to document the research trend of this subject area in order to identify the past contributions, research gap(s) and also to predict the future direction.

Scholars have published ANN review studies relating to finance (Wong and Selvi, 1998), business (Wong et al., 1997), HIV epidemic (Sibanda and Pretorius, 2012), market segmentation (Chattopadhyay et al., 2012), reliability analysis of steel construction (Chojaczyk et al., 2015), civil engineering (Flood and Kartam, 1994; Adeli, 2001), clothing comfort (Utkun, 2014) and construction management (Boussabaine, 1996), amongst others. However, no similar effort has been documented in the real estate appraisal domain. To this end, this study aims to review property valuation ANN related studies in order to present the framework for the application of ANN in property price prediction and also to establish the trend in this research area. This would provide both real estate researchers and professionals with a guide and insight into the application of the ANN model and also an overview of this research area to all property valuation stakeholders.

2. Research method

The essence of providing a detailed research method adopted in a research study is to allow the replicability of such study (Laryea and Leiringer, 2012). A systematic review of the literature

is an efficient and appropriate approach that can be adopted to identify and evaluate an existing range of literatures (Mulrow, 1994). A better understanding of a research area can be presented through a systematic review when compared with an individual study (Campbell et al., 2003). Also, it could be used to develop a reliable knowledge base from a pool of studies which can be useful to both researchers and industry practitioners (Tranfield et al., 2003). Hence, this study has adopted a systematic review approach. To this end, property valuation articles that adopted the ANN model constitute the data for the present study. The data were retrieved from online databases and search engines such as Scopus, Taylor and Francis, ProQuest and Google Scholar. Articles that were published in journals, conference proceedings and sections of books were retrieved. It must be stated that studies in which the ANN was not actually applied to property valuation were excluded during the search process. The start date was left open so as to retrieve the earliest paper that adopted ANN in the real estate research domain, while the end date was put at 2015. Consequently, 31 relevant articles that met the selection criteria were retrieved from the search. Of the 31 articles, 28 were journal articles, two were conference proceedings, while only one was a book section. This search approach is similar to that adopted by Al-Sharif and Kaka (2004) and Ke et al. (2009) to identify the research trend of construction management research in construction journals. ANN related studies applied in other field of studies were also reviewed in order to retrieve some common background and details of the ANN technique.

The keywords used for the real estate related papers retrieved include “artificial neural network”, “artificial neural network and hedonic pricing model”, “artificial neural network versus hedonic pricing model”, “artificial neural network in real estate”, “property price prediction”, “property value forecasting”, “property price modeling”, “artificial intelligence property appraisal” and “mass appraisal using artificial neural network”. A physical visual examination of the populated articles was performed in order to select articles that actually adopted the ANN model. The retrieved articles were subjected to a thorough analysis in order to retrieve meaningful inferences from the articles. The information extracted include the names of authors, the authors’ affiliations, the sample size of data used for the analysis, the

number of input variables, the year of publication, the journals in which the articles were published, the country of origin of the articles, the software used for the construction of the models and the ANN architecture adopted for the development of the models. These information are presented sequentially in tables and was eventually analysed in order to draw meaningful conclusions from the review of the literature.

3. The artificial neural network modeling technique

3.1 Background and theory of artificial neural network

The origin of the neural network can be traced to McCulloch and Pitts (1943) who attempted to model the neuron by demonstrating that neural networks can work out arithmetic logical functions. According to Zhang et al. (1998), the first application of ANN for forecasting was conducted by Hu (1964) who explored the technique for weather forecasting by using Widrow's adaptive linear network. But at that time, no multilayer network training algorithms existed, therefore, the technique did not receive much attention. The operation of the network is based on the interaction of the neurons. Neurons are interconnected and function by receiving commands from the 'Dendrites' (connectors) and after processing the information, it is passed to the other neuron by the 'Axons' (connectors) (Mora-Esperanza, 2004). The structure of a neuron is presented in Figure 1.

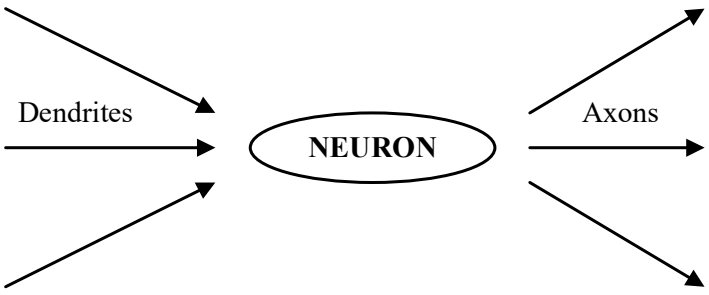

Figure 1: The structure of a neuron
Adopted from: Mora-Esperanza (2004, p. 256).

According to Wong et al. (2002), the operation of ANN as presented in Figure 2, starts with an activation function that integrates the input values. This information is then transferred to the hidden layer. The operation in the hidden layer is in two stages; "the weighted summation

functions and the transformation functions" (Pagourtzi et al., 2007, p. 53). The weights are transferred through an activation process to the sigmoid transformation function, from where the output is produced.

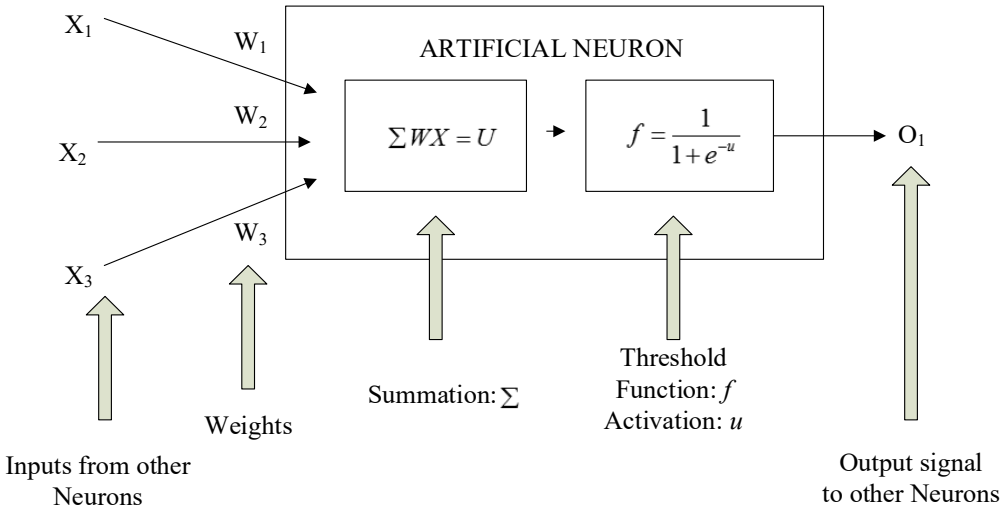

Figure 2: The components of a typical processing unit
Adopted from: Wong et al. (2002, p. 190).

Where X_{1-3} are the input value, W_{1-3} are the assigned weights of the input values, *U* is the summation function, while *f* is the threshold value where output is determined.

The transfer function "determines the relationship between input and output of a neuron and its network" (Lin and Mohan, 2011, p. 234) and there are different forms of transfer functions such as linear functions, linear threshold functions, step linear functions and sigmoid functions (Pagourtzi et al., 2007; Krenker et al., 2011). The most widely used is the sigmoid function (Mora-Esperanza, 2004), probably because it is "advantageous within the context of many paradigms" (Ge, 2004, p. 139), and easy to apply in computer programming (Mora-Esperanza, 2004).

3.2 Construction of artificial neural network model

The process of applying the ANN model to a problem involves a number of steps. These steps are not a one-off procedure because the steps are iterative until an optimal ANN network is

identified. Kaastra and Boyd (1996) documented a detailed process of developing an ANN model which involved eight main steps. However, Ge (2004) presented a systematic process of developing an ANN model as shown in Figure 3.

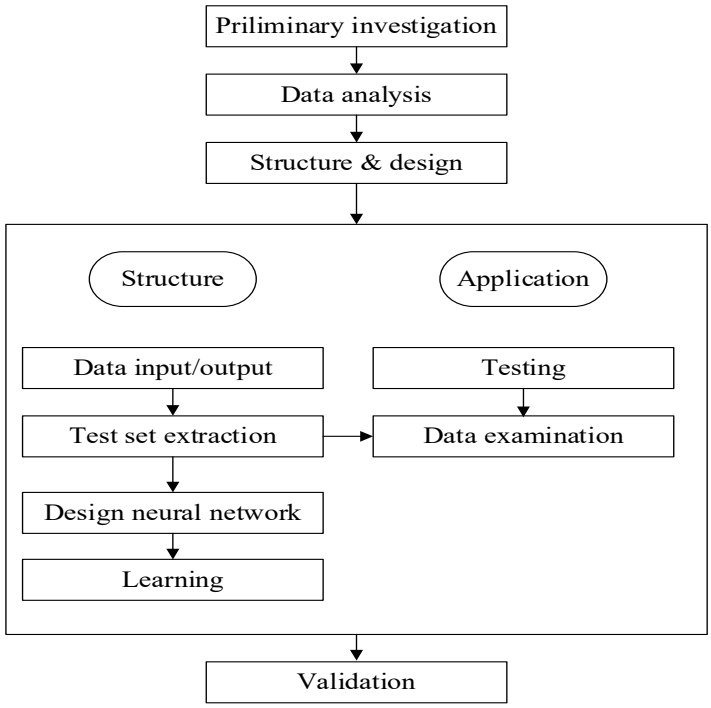

Figure 3: ANN model development process
Adopted from: Ge (2004, p. 149).

In applying ANN to property valuation, historical property transaction data of the property market under investigation is required. The ANN model can then be processed to 'learn' from the input data. This sales transaction data comprise of the property attributes (ANN input) and property prices (ANN output). The data set available for the construction of the ANN model is to be divided into two sets; the first is used for the 'training' while the other is used for 'verification and testing' of the model (Wilson et al., 2002). The training data set is utilized for the construction of the model, whereas, the testing data set is used for the evaluation of the predictive ability of the developed model (Lam et al., 2008). Although there is no consensus as to the sharing ratio of data set (Cechin et al., 2000), Ge et al. (2003) recommended a sharing

ratio of 60:20:20 for training, testing and production, respectively. Nonetheless, a ratio of 80:20, i.e. for training and testing/validation, respectively, is common in the literature. This is because a small data set is sufficient for model testing (Zhang et al., 1998).

3.3 Artificial neural network architecture and model development

The construction of the ANN network is referred to as the "network architecture". There are three types of network architectures viz: recurrent network, single-layer feedforward network and multi-layer feedforward network (De Castro and Timmis, 2002). However, the feedforward/back-propagation network ANN model is commonly applied in property valuation (Selim, 2009; McCluskey et al., 2013).

The ANN model consists of three layers, namely input, hidden and output layer. At the input layer, input variables that represent property attributes are fed into the network. The hidden layer is the layer in-between the input and output layer where mathematical processing takes place. The result of the transformation that takes place in the hidden layer is produced at the output layer, which is where the predicted property value is obtained.

Mora-Esperanza (2004) posited that an input variable size of between 10 and 50 is common for the construction of ANN models for property valuation, and that the number of hidden layers can range between half and double the number of input variables. Although Hornik (1991) and Masters (1993) argued that one hidden layer is sufficient for an ANN model to perform excellently. The output layer usually have one neuron, which is the predicted property value.

The number of neurons used in the hidden layer of a model can aid the retrieval of an improved result (Borst, 1995), but unfortunately, there is no consensus in the literature as regards the number of hidden neurons to be included in an ANN model (Cechin et al., 2000). Nevertheless, Ward (1996) presented an expression that can be used in determining the number of neurons in the hidden layer which is presented in Equation 1.

$$N_h = \frac{N_{in} + N_{out}}{2} + \sqrt{N_s} \qquad (1)$$

Where N_h is the number of neurons of hidden layer, N_{in} is input layer, N_{out} is output layer and N_s is the number of training samples.

A typical ANN model architecture is presented in Figure 4. The architecture depicts a scenario of a model that has six input variables, one hidden layer (with three neurons) and one output layer.

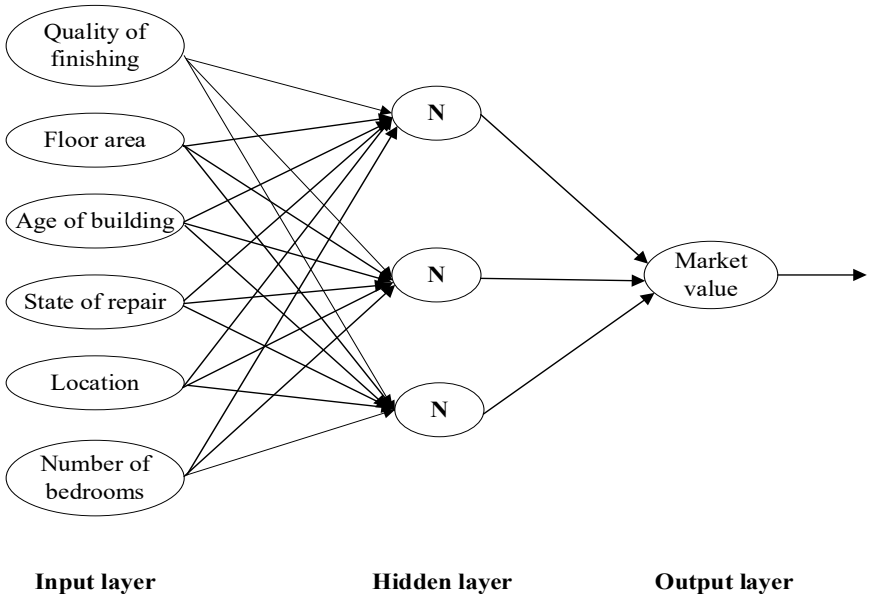

Figure 4: A simple ANN model for real estate valuation

Adapted from: Mora-Esperanza (2004, p. 257) and Taffese (2006, p. 711).

The number of samples needed to construct an ANN model is not established in the literature. However, Rossini (1997, p. 9) mentioned that a 'small data set' is sufficient for the construction of an ANN model. The ANN model do not need more data than usually required by linear models for it to function excellently (Zhang et al., 1998). From another view, Mora-Esperanza (2004) posited that the number of samples should be proportional to the number of variable entries.

The need for the ANN model to 'learn' like the human brain make its operation to be based on a 'trial and error' process to determine the best optimal ANN model (Cechin et al., 2000; Limsombunchai et al., 2004; Lin and Mohan, 2011). This is because ANN learns from experience like a new baby when mastering the act of talking or walking.

3.4 Strengths and weaknesses of artificial neural network

The emergence of the ANN model in the property valuation domain has addressed the technical limitations of the linear model approaches (Do and Grudnitski, 1992; Tay and Ho, 1992; Worzala et al., 1995). The ANN modeling technique has proven to be a better alternative to the commonly adopted hedonic pricing model (HPM) in property appraisal due to its adaptability (Taffese, 2006) and generalization (Xie and Hu, 2007) capabilities. The model can handle the nonlinear relationship that exists between property values and property attributes (Cechin et al., 2000), and easy to operate (Borst, 1991). It can also address the 'time variant problem and even under uncertain or erroneous attributes of real estate valuation' (Taffese, 2006, p. 712).

Some other valuation approaches for instance, the comparison method and HPM are characterized by subjectivity (Kauko, 2004; Yacim and Boshoff, 2014), whereas developing the ANN model does not require human input (Tay and Ho, 1992). In the operation of ANN, a priori theory is not needed to analyse the nonlinear or complex nature that exist between property values and property attributes (Worzala et al., 1995). At the same time, the ANN model produces estimates (output) that are highly precise, handles data set that contain outliers and it is also user friendly (Mora-Esperanza, 2004).

ANN is an advanced property modeling technique that comes with some shortcomings. McGreal et al. (1998), Limsombunchai et al. (2004) and Lam et al. (2008) opined that the 'black-box' nature of ANN and the lack of the interpretation of the produced output are some of the limitations of the modeling technique. However, the development of different software has been handling some of the challenges of the ANN model (McCluskey et al., 2012) and also the consistent improvement in the theory of the model in different field of studies has been improving the performance of the ANN technique. For example, ANN is being use to conduct sensitivity analysis of property attribute in order to establish the most important property value determinants (see Lai, 2011; Morano et al., 2015). Since the aim of a valuer is to arrive at a reliable and precise estimate that will be a good proxy of open market value, the need to fully understand how the output is been generated may not be significant, because the main reason

for embarking on a valuation exercise is to estimate reliable and acceptable valuation figures (McCluskey, 1996).

4. Application of artificial neural network in real estate

The application of the ANN model to property valuation could be traced to the early 1990s. Borst (1991) was the first to apply the ANN model to property appraisal. The study presented a description of the ANN technique and examined the predictive accuracy ability of the ANN model under four cases using different network architecture. Borst (1991) concluded that the forecasting accuracy produced by the ANN model is reliable and that with more research efforts towards the application of ANN to the real estate appraisal, the model would produce outstanding results.

After Borst (1991) seminal study, other scholars have applied ANN to property valuation problems. Kathmann (1993) presented an overview of the application of ANN in property valuation and also evaluated the significance of the technique. The author found ANN to be more superior to other property valuation techniques. In a similar vein, McGreal et al. (1998) applied ANN in predicting property values using 1,026 Belfast property sales data. In an attempt to avoid bias in the data utilized, the authors restricted the data to transactions completed between 1992 and 1993. The predictive ability of the ANN model was confirmed in the study. The approach produced accurate and consistent outputs both in the 1992 and 1993 models. The authors documented the excellent accurate predictive ability of ANN, but suggested that more effort should be invested in researching on how to make the ANN technique perfect.

More property markets around the world have been modeled using ANN. A summary of some studies are presented in Tables I, II and III. The information in Table I shows that the technique has produced encouraging results in different property markets around the world, as reported in all the studies.

Table I. Studies of ANN application in real estate appraisal

Authors	Country	Sample size/no. of variables	Training: testing ratio	Model architecture	Software employed	Summary of findings
Borst (1995)	United States	217/11	90:10	11-9-1	BrainMaker Professional	ANN predicted more accurately than HPM
McCluskey (1996)	Ireland	416/9	90:10	17-15-5-1	-	ANN produced excellent realistic output
Wilson et al. (2002)	United Kingdom	?	80:20	5-TE-8	-	ANN is a promising forecasting technique
Ge and Runeson (2004)	Hong Kong	88/18		18-TE-1	-	ANN is an effective forecasting technique
Mora-Esperanza (2004)	Spain	100/12	85:15	12-7-1	Spreadsheet	ANN is appropriate for property value forecasting
Lam et al. (2008)	Hong Kong	4,143/29	80:20	30 models	NeuroShell 2	ANN is a viable property forecasting tool
Tabales, Ocerin and Carmona (2013)	Spain	10124/6	80:20	6-6-1	Trajan Software	ANN is an effective forecasting technique
Ahmed, Rahman and Islam (2014)	Bangladesh	100/40	70:30	40-10-1	Matlab Software	ANN is an alternative to HPM
Morano, Tajani and Torre (2015)	Italy	90/7	80:20	8-13-1	BKP - Neural Network Simulator	ANN predicted excellently

Note: TE means trial and error, ? means not available and – means not provided.

4.1 Artificial neural network and other property price prediction techniques

The ANN technique has being gaining rapid popularity amongst real estate researchers (Adhikari and Agrawal, 2013), and this has led to a number of studies conducted in different property markets around the world to establish the predictive ability of the ANN model and other appraisal techniques, especially the HPM technique. The likeness between the ANN and other statistical analysis techniques has allowed its comparison with these models (Brunson et al., 1994). For the ANN models developed in different property markets around the world, an average absolute error of between 5 and 7.5 percent was widely reported (Jenkins, 2000), while the rate is between 10 and 15 percent for HPM (Mora-Esperanza, 2004).

Table II. Summary of ANN and other appraisal techniques comparative studies

Authors	Country	Sample size/ no. of variables	Summary of findings
Do and Grudnitski (1992)	United States	163/8	ANN better than HPM
Tay and Ho (1992)	Singapore	1,055/10	ANN better than HPM
Worzala et al. (1995)	United States	288/8	ANN not totally better than HPM
Lenk, Worzala and Silva (1997)	United States	288/7	ANN did not outperform HPM
Rossini (1997)	Australia	334/12	Superiority of ANN over HPM is inconclusive
Cechin et al. (2000)	Brazil	1,600/6	ANN better than HPM
Din, Hoesli and Bender (2001)	Switzerland	285/15	ANN is more promising than HPM
Nguyen and Cripps (2001)	United States	3,906/6	ANN outperformed HPM

Wong et al. (2002)	Hong Kong	251/12	ANN is an alternative to HPM
Limsombunchai et al. (2004)	New Zealand	200/13	ANN outperformed HPM
Özkan, Yalpır and Uygunol (2007)	Turkey	170/7	ANN outperformed HPM
Pagourtzi et al. (2007)	Greece	141/13	ANN is a better alternative to HPM
Selim (2009)	Turkey	5,741/46	ANN is a better alternative to HPM
Peterson and Flanagan (2009)	United States	46,467/7	ANN better than HPM
Lai (2011)	Taiwan	2471/9	ANN is a better alternative to HPM
Lin and Mohan (2011)	United States	33,342/7	ANN is more reliable than HPM and ANR
Zurada, Levitan and Guan (2011)	United States	16,366/18	ANN is not actually superior than other techniques
Amri and Tularam (2012)	Australia	7,849/10	ANN outperformed HPM and FLS
McCluskey et al. (2013)	Northern Ireland	2,694/6	ANN not better than HPM and GWR
Morano and Tajani (2013)	Italy	85/6	ANN outperformed HPM
Sampathkumar, Santhi and Vanjinathan (2015)	India	204/13	ANN more accurate than HPM

Note: ANR - additive nonparametric regression, FLS – fuzzy logic system, GWR means geographically weighted regression

The results of the comparative studies may be mixed, but the ANN model has produced more accurate estimates than other modeling techniques (Mora-Esperanza, 2004). The information in Table II showcases the summary of comparative studies of the ANN model and other appraisal techniques. In 16 out of the 21 studies, the ANN model was found to either outperform or be a good alternative to HPM and other techniques, while only a few studies reported an inconclusive result as to the predictive ability of the ANN model.

4.2 An overview of artificial neural network property valuation studies

A summary of the details of the ANN studies retrieved from the literature is presented in Table III. This summary presents the past contributions of researchers to this research debate over the years in terms of the year of publication, the countries where the articles emanated from, affiliations of the authors and the name of journal, the conference or book where the articles were published in.

Table III. Details of the artificial neural network studies

Studies	Year of publication	Origin (Country)	Organization	Journal of publication
Borst (1991)	1991	United States	Day & Zimmerman, Inc., United States	Property Tax Journal
Do and Grudnitski (1992)	1992	United States	San Diego State University	The Real Estate Appraiser
Tay and Ho (1992)	1992	Singapore	National University of Singapore	Journal of Property Valuation and Investment
Borst (1995)	1995	United States	Day & Zimmerman, Inc., United States	Journal of property Tax Assessment & Administration
Worzala et al. (1995)	1995	United States	Colorado State University, United States	Journal of Real Estate Research
McCluskey (1996)	1996	Northern Ireland	University of Ulster, Northern Ireland	New Zealand Valuers Journal
Lenk et al. (1997)	1997	United States	Colorado State University, United States	Journal of Property Valuation and Investment
Rossini (1997)	1997	South Australia	University of South Australia, Australia	Australian Land Economics Review
McGreal et al. (1998)	1998	Northern Ireland	University of Ulster, Northern Ireland	Journal of Property Valuation and Investment
Cechin et al. (2000)	2000	Brazil	UNISINOS University, Brazil	Proceedings of 6th Brazilian Symposium on Neural Networks, Rio de Janeiro, Brazil**
Din et al. (2001)	2001	Switzerland	Inter-Survey Consultants and Université de Genève, HEC, Switzerland	Urban Studies
Nguyen and Cripps (2001)	2001	United States	Middle Tennessee State University	Journal of Real Estate Research
Wong et al. (2002)	2002	Hong Kong	University of Hong Kong, Hong Kong	Real Estate Valuation Theory***
Wilson et al. (2002)	2002	United Kingdom	University of Glamorgan	Knowledge-Based Systems
Ge and Runeson (2004)	2004	Hong Kong	UNITEC New Zealand and University of NSW, Australia	International Real Estate Review
Limsombunchai et al. (2004)	2004	New Zealand	Lincoln University and American University of Sharjah, UAE	American Journal of Applied Sciences
Mora-Esperanza (2004)	2004	Spain	Dirección General del Catastro de España	Catastro
Özkan et al. (2007)	2007	Turkey	Selcuk University and Bilge Mühendislik, Turkey	Proceedings of 12th ASMDA, International Conference, Chania, Crete, Greece**

Pagourtzi et al. (2007)	2007	Greece	National Technical University of Athens, Ministry of Economy & Finance Athens and Lancaster University Management School, Lancaster	International Journal of Intelligent Systems Technologies and Applications
Xie and Hu (2007)	2007	China	Guangdong University of Technology, China	3rd International Conference on Natural Computation, Haikou**
Lam et al. (2008)	2008	Hong Kong	City University of Hong Kong, Hong Kong	Journal of Property Research
Peterson and Flanagan (2009)	2009	United States	Virginia Commonwealth University and Williams Appraisers, United States	Journal of Real Estate Research
Selim (2009)	2009	Turkey	Dokuz Eylul University, Turkey	Expert Systems with Applications
Zurada et al. (2011)	2011	United States	University of Louisville, United States	Journal of Real Estate Research
Lin and Mohan (2011)	2011	United States	State University of New York, United States	International Journal of Housing Markets and Analysis
Amri and Tularam (2012)	2012	Australia	Griffith University, Australia	Journal of Mathematics and Statistics
McCluskey et al. (2013)	2013	Ireland	University of Ulster, Ireland UK	Journal of Property Research
Morano and Tajani (2013)	2013	Italy	Polytechnic of Bari, Italy and University of Studies of Salerno, Italy	International Journal of Business Intelligence and Data Mining
Tabales et al. (2013)	2013	Spain	University of Cordoba, Spain	La Economia Y La Empresa
Ahmed et al. (2014)	2014	Dhaka	Bangladesh University of Business and Technology, Dhaka, Bangladesh	International Journal of u-and e-Service, Science and Technology
Morano et al. (2015)	2015	Italy	Polytechnic of Bari, Italy	Advances in Environmental Science and Energy Planning

Note: ** means conference proceeding and *** means book section

5. Discussion

As Mora-Esperanza (2004) mentioned that an input variable size of between 10 and 50 is common for the construction of an ANN model for real estate appraisal, this is affirmed in Tables I and II, where it is shown that the ANN model was constructed with as low as six variables and as many as 40 variables. At the same time, as little as 90 and as high as 46,467 sample data were used for the ANN model development by scholars and this confirms the fact that ANN does not require too many samples for it to function properly (Rossini, 1997; Zhang et al., 1998). This proves that the ANN technique can be applied successfully even in property markets where there is a paucity of sales transaction data (Kang, 1991), and also in a situation where a centralized property sales databank do not exist (Oduwole and Eze, 2013), which could be the case in most developing countries (Walters et al., 2011; Owusu-Ansah, 2012; Adegoke, 2016). However, it must be noted that the use of ANN in property valuation related studies have grown. ANN has been applied to larger data sets in the post-2000 studies in the real estate field. There are several reasons for this. For example, the increased availability of data for real estate research in developed countries (Sirmans and Worzala, 2003). In recent years, the emergence of big data analysis suggest that sound investment decisions could be taken by stakeholders when real estate transaction information are available (Fuerst et al., 2016). On the

testing and training division ratio, the ratio of 80:20 seems common in the literature, but researchers will employ their discretion in dividing the data set (Cechin et al., 2000).

As shown in Table I, the ANN architecture varies. This corroborates the assertions found in the literature (Limsombunchai et al., 2004; Lin and Mohan, 2011) which suggests that the development of ANN model is based on an iterative process. The mathematical form of the ANN model is not seen by the expert (Lenk et al., 1997; Mora-Esperanza, 2004). This is due to the nonlinearity associated with the ANN model. Also, it is widely known that valuation estimates are greatly affected by changes in the macroeconomic climate of a country (Witten, 1987). An over-valuation could be experienced in a period of boom, while in a period of economic recession, under-valuation could be prevalent (Dunse et al., 2010). This is the reason for the deflation of property prices from current prices to constant prices as observed in several studies (see, Zurada et al., 2006; McCluskey et al., 2012).

The heterogeneous nature of a subject property market may also affect the accuracy of valuation estimates, and in a situation where there is a substantial constraints in the supply of properties in a property market, property valuation inaccuracy may be unavoidable (Dunse et al., 2010). However, dummy variables can be included in the model development to capture the effects of these external factors on the predicted value (see for instance, Tay and Ho, 1992; McGreal et al., 1998; Zurada et al., 2011; McCluskey et al., 2012; Mimis et al., 2013). The process of property valuation involves both the ‘art’ and the ‘science’ in order to estimate

property value (Kummerow, 2003; Azmi et al., 2013). By this, the valuer incorporates both 'heuristics' and 'mathematical model' in interpreting property values (Warren-Myers, 2015). This suggests that a valuer must possess a solid knowledge of the property market under consideration in order to successfully apply the ANN model and report a reliable valuation estimate (Hager and Lord, 1985; Shapiro et al., 2012). For instance, the valuer's will rely on heuristics in collecting information of the property attributes that significantly influence property values in the study area that will used in developing the model (Grover, 2016). Suggesting that the ANN and other modeling techniques are not to replace the valuer in property valuation (Lenk et al., 1997). This is obvious in the situation where "various countries having included the ANN in their real estate valuation computer system, as a help tool for their valuators" (Mora-Esperanza, 2004, p. 260) . Therefore, an appraiser's expert knowledge is noteworthy for property valuation.

The information in Table I corroborates the position of researchers (McCluskey, 1996; Wong et al., 2002) that different software is being designed for constructing an ANN model which is making it user more friendly. The software employed include spreadsheet, NeuroShell2, Matlab and BrainMaker Professionals, amongst other software. Some of these software are available free online, while some are commercialized. For instance, Waikato Environment for Knowledge Analysis (WEKA) software can be downloaded free online (Witten and Frank, 2005), likewise the R tool (Cortez, 2010). All this boil down to the fact that no model or

approach fits all appraisal situations (Tse, 1997). As shown in Table II, in most of the instances, the ANN model outperformed other modeling and statistical appraisal techniques. This established accurate predictive ability of the ANN model makes it a valuable tool for property valuation. The adoption of a more reliable and accurate valuation technique could lead to a reduction in the level of valuation inaccuracy in property valuation estimates (Grover, 2016).

As regards the yearly distribution of the publications as shown in Table III, nine articles were published between the first decade (1990 -1999) of the introduction of the technique to the real estate domain, 14 were published between 2000 and 2009, while eight have been published from 2010 to 2015. This signifies that after the maiden application of ANN to property valuation in the early 1990s, it received much attention by researchers during the second decade of application and has continue to gain popularity amongst researcher (Adhikari and Agrawal, 2013). This could be attributed to the improvements in its theory and application (Wong et al., 2002). In terms of the country of origin of the articles, about 26 percent of these studies emanated from the United States, while the rest were conducted in other real estate markets around the world, with the majority originated from developed economies. In a related research domain (Construction Management) most of the published articles emanated from developed countries, especially the United States (see Yi and Chan, 2013; Darko and Chan, 2016). There are several reasons for this observation. First, the volume of funds available for research activities in the developed world (Man et al., 2004). Second, leadership and interest of

academic staff are factors that influence research productivity (Ramsden, 1994). Finally, Falagas et al. (2006) suggest that there is a need for more collaboration between researchers in developed and developing countries. This shows a clear gap between the application of ANN in developed countries and developing countries and by bridging this gap, developing property markets could attain a standard international property valuation practice.

The details in the fourth column in Table III shows the affiliations of the authors when the researches were conducted. It is clear that most of the authors were faculty members of universities, while a few real estate practitioners affiliated to research institutes, real estate firms and government organizations contributed to this research topic. This corroborates the findings of Adewunmi and Olaleye (2011) and the position of Jenkins et al. (1999) that university scholars are the highest contributors to real estate research compared to professionals, which is also the same in the construction management field of study (see Al-Sharif and Kaka, 2004). However, it is pertinent to note that the first application of this technique in the real estate domain was conducted by an industry practitioner, which suggests that practice and research are vital for the sustainability of any profession (Hemsley-Brown and Sharp, 2003). Most of the articles (87 percent) were published in journals, while others were published in conference proceedings and book chapter. This indicates that research efforts in this area have been published through different publication means, which will aid wider circulation of research findings.

6. Conclusion

An attempt has been made in this study to review property valuation ANN related studies in order to provide an application framework for real estate researchers and professionals and also identify the trend in this research area. Articles published in journals, conference proceedings and book sections were retrieved from online databases and search engines and were reviewed. This analysis reveals that in applying the ANN model to property valuation, there is flexibility in its operation. This is because, the construction of the ANN model permits little sample data, few variables can be employed, different network architecture can be designed for its construction and quite a number of software can be used for its analysis. This study establishes the good predictive ability of the ANN model over other appraisal techniques from the reviewed articles. However, the principles of its application should be strictly adhered to in order to achieve a reliable and accurate valuation estimate. It was also discovered that the majority of the articles retrieved for this study emanated from developed countries, particularly the United States, with most of the studies also been conducted by university scholars. Addressing this gap could lead to a change in the appraisal practice of developing countries to international standard. This could be achieved probably by encouraging university scholars and practitioners in the emerging property markets to embrace the adoption of artificial intelligence in the property valuation both in research and in practice. The gap identified in this study could

also spur collaboration between researchers and practitioners in both developed and developing countries, which could lead to a sustainable real estate appraisal research and practice.

The articles reviewed in this study may not be the total sum of studies that have been conducted in this research area. Some studies might have been omitted because they are not indexed in the databases explored or not available in the public domain. Therefore, the findings of this paper should be carefully generalized. It is expedient to mention at this point that this present study is a preliminary study of a wider-scoped research that aims at adopting the ANN model in modeling the Nigerian residential property market, which is the giant of Africa, but still at the developing stage.

Acknowledgements

The authors sincerely acknowledge the Research Grants Council of Hong Kong (SAR) and the Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong for providing financial and material support towards this research. We also appreciate the constructive comments of the anonymous reviewers during the review process.

References

Abidoye, R. B. and Chan, A. P. C. (2016). A survey of property valuation approaches in Nigeria. *Property Management, 34*(5), 364-382.

Adegoke, O. J. (2016). Effects of valuation variance and inaccuracy on Nigerian commercial property market: An empirical study. *Journal of Property Investment & Finance, 34*(3), 276-292.

Adeli, H. (2001). Neural networks in civil engineering: 1989–2000. *Computer-Aided Civil and Infrastructure Engineering, 16*(2), 126-142.

Adewunmi, Y. A. and Olaleye, A. (2011). Real estate research directions and priorities for Nigerian institutions. *Journal of Real Estate Practice and Education, 14*(2), 125-140.

Adhikari, R. and Agrawal, R. (2013). An introductory study on time series modeling and forecasting. Retrieved 12 July 2016, from arXiv, Cornell University http://arxiv.org/ftp/arxiv/papers/1302/1302.6613.pdf

Al-Sharif, F. and Kaka, A. (2004). *PFI/PPP topic coverage in construction journals.* Paper presented at the 20th Annual ARCOM Conference, Edinburgh, UK.1-3 September.

Azmi, A. S. M., Nawawi, A. H., Ab Latif, S. N. F. and Ling, N. L. F. J. (2013). Property valuers' receptive level on knowledge of computer aided valuation (CAV) system. *Procedia-Social and Behavioral Sciences, 105*, 734-744.

Bagnoli, C. and Smith, H. C. (1998). The theory of fuzz logic and its application to real estate valuation. *Journal of Real Estate Research, 16*(2), 169-200.

Borst, R. A. (1991). Artificial neural networks: The next modelling/calibration technology for the assessment community. *Property Tax Journal, 10*(1), 69-94.

Borst, R. A. (1995). Artificial neural networks in mass appraisal. *Journal of Property Tax Assessment & Administration, 1*(2), 5-15.

Boussabaine, A. H. (1996). The use of artificial neural networks in construction management: A review. *Construction Management & Economics, 14*(5), 427-436.

Brunson, A., Buttimer Jr, R. and Rutherford, R. (1994). Neural networks, nonlinear specifications, and industrial property values *Working Paper Series*. Texas, USA: University of Texas at Arlington.

Campbell, R., Pound, P., Pope, C., Britten, N., Pill, R., Morgan, M. and Donovan, J. (2003). Evaluating meta-ethnography: A synthesis of qualitative research on lay experiences of diabetes and diabetes care. *Social Science & Medicine, 56*(4), 671-684.

Cechin, A., Souto, A. and Gonzalez, A. M. (2000). *Real estate value at Porto Alegre city using artificial neural networks.* Paper presented at the 6th Brazilian Symposium on Neural Networks, Rio de Janeiro, Brazil.22-25 November.

Chattopadhyay, M., Dan, P. K., Mazumdar, S. and Chakraborty, P. S. (2012). Application of neural network in market segmentation: A review on recent trends. *Management Science Letters, 2*(1), 425-438.

Chojaczyk, A., Teixeira, A., Neves, L., Cardoso, J. and Soares, C. G. (2015). Review and application of Artificial Neural Networks models in reliability analysis of steel structures. *Structural Safety, 52*(1), 78-89.

Cortez, P. (2010). *Data mining with neural networks and support vector machines using the R/rminer tool.* Paper presented at the 10th Industrial Conference on Data Mining, Berlin, Germany.12 - 14 July.

Darko, A. and Chan, A. P. (2016). Critical analysis of green building research trend in construction journals. *Habitat International, 57*(1), 53-63.

De Castro, L. N. and Timmis, J. (2002). *Artificial immune systems: A new computational intelligence approach*. Great Britain: Springer Science & Business Media.

Do, A. Q. and Grudnitski, G. (1992). A neural network approach to residential property appraisal. *The Real Estate Appraiser, 58*(3), 38-45.

Dunse, N., Jones, C. and White, M. (2010). Valuation accuracy and spatial variations in the efficiency of the property market. *Journal of European Real Estate Research, 3*(1), 24-45.

Elhag, T. (2002). *Tender price modeling: Artificial neural network and regression techniques.* (Doctoral dissertation), University of Liverpool, United Kingdom.

Falagas, M. E., Karavasiou, A. I. and Bliziotis, I. A. (2006). A bibliometric analysis of global trends of research productivity in tropical medicine. *Acta Tropica, 99*(2), 155-159.

Flood, I. and Kartam, N. (1994). Neural networks in civil engineering. I: Principles and understanding. *Journal of Computing in Civil Engineering, 8*(2), 131-148.

Fuerst, F., Liu, X. and Lizieri, C. (2016). A Commercial real estate index for an emerging market: The case of Beijing (pp. 1-20). Cambridge, UK: University of Cambridge.

Ge, J. X. (2004). *Housing price models for Hong Kong.* (Doctoral dissertation), University of Newcastle, Australia.

Ge, J. X., Runeson, G. and Lam, K. C. (2003). *Estimation Hong Kong housing prices: An artificial neural network approach.* Paper presented at the ENHR/IAPS International Conference 'Methodologies in Housing Research', Stockholm, Sweden.22-24 September.

Grover, R. (2016). Mass valuations. *Journal of Property Investment & Finance, 34*(2), 191-204.

Hager, D. P. and Lord, D. J. (1985). The property market, property valuations and property performance measurement. *Journal of the Institute of Actuaries, 112*(1), 19-60.

Hemsley-Brown, J. and Sharp, C. (2003). The use of research to improve professional practice: A systematic review of the literature. *Oxford Review of Education, 29*(4), 449-471.

Hornik, K. (1991). Approximation capabilities of multilayer feedforward networks. *Neural Networks, 4*(2), 251-257.

Hu, M. J.-C. (1964). Application of the adaline system to weather forecasting. Stanford, CA: Stanford Electronic Laboratories.

Jenkins, D. (2000). *Residential valuation theory and practice*. Oxford: Chandos Publishing.

Jenkins, D., Lewis, O., Almond, N., Gronow, S. and Ware, J. (1999). Towards an intelligent residential appraisal model. *Journal of Property Research, 16*(1), 67-90.

Jiang, H., Jin, X.-H. and Liu, C. (2013). The effects of the late 2000s global financial crisis on Australia's construction demand. *Australasian Journal of Construction Economics and Building, 13*(3), 65-79.

Kaastra, I. and Boyd, M. (1996). Designing a neural network for forecasting financial and economic time series. *Neurocomputing, 10*(3), 215-236.

Kang, S. Y. (1991). *An investigation of the use of feedforward neural networks for forecasting.* (Doctoral dissertation), Kent State University Kent,, OH, USA.

Kathmann, R. M. (1993). Neural networks for the mass appraisal of real estate. *Computers, Environment and Urban Systems, 17*(4), 373-384.

Kauko, T. (2004). Towards the 4th generation-an essay on innovations in residential property value modelling expertise. *Journal of Property Research, 21*(1), 75-97.

Ke, Y., Wang, S., Chan, A. P. and Cheung, E. (2009). Research trend of public-private partnership in construction journals. *Journal of Construction Engineering and Management, 135*(10), 1076-1086.

Krenker, A., Kos, A. and Bešter, J. (2011). Introduction to the artificial neural networks. In S. Kenji (Ed.), *Artificial Neural Networks - Methodological Advances and Biomedical Applications* (pp. 362). Rijeka, Croatia: INTECH Publisher.

Kummerow, M. (2003). Theory for real estate valuation: An alternative way to teach real estate price estimation methods. Perth: Department of Land Economy and Valuation, Curtin University.

Lai, P. Y. (2011). Analysis of the mass appraisal model by using artificial neural network in Kaohsiung city. *Journal of Modern Accounting and Auditing, 7*(10), 1080-1089.

Lam, K. C., Yu, C. Y. and Lam, K. Y. (2008). An artificial neural network and entropy model for residential property price forecasting in Hong Kong. *Journal of Property Research, 25*(4), 321-342.

Laryea, S. and Leiringer, R. T. F. (2012). *Built environment research in West Africa: Current trends and future directions.* Paper presented at the West Africa Built Environment Research (WABER) Conference, Abuja, Nigeria.24 - 26 July.

Lenk, M. M., Worzala, E. M. and Silva, A. (1997). High-tech valuation: Should artificial neural networks bypass the human valuer? *Journal of Property Valuation and Investment, 15*(1), 8-26.

Limsombunchai, V., Gan, C. and Lee, M. (2004). House price prediction: Hedonic price model vs. artificial neural network. *American Journal of Applied Sciences, 1*(3), 193-201.

Lin, C. C. and Mohan, S. B. (2011). Effectiveness comparison of the residential property mass appraisal methodologies in the USA. *International Journal of Housing Markets and Analysis, 4*(3), 224-243.

Man, J. P., Weinkauf, J. G., Tsang, M. and Sin, J. H. D. D. (2004). Why do some countries publish more than others? An international comparison of research funding, English proficiency and publication output in highly ranked general medical journals. *European journal of epidemiology, 19*(8), 811-817.

Masters, T. (1993). *Practical neural network recipes in C++*. Boston: academic Press.

McCluskey, W. (1996). Predictive accuracy of machine learning models for the mass appraisal of residential property. *New Zealand Valuers Journal, 16*(1), 41-47.

McCluskey, W., Davis, P., Haran, M., McCord, M. and McIlhatton, D. (2012). The potential of artificial neural networks in mass appraisal: The case revisited. *Journal of Financial Management of Property and Construction, 17*(3), 274-292.

McCluskey, W. J., McCord, M., Davis, P., Haran, M. and McIlhatton, D. (2013). Prediction accuracy in mass appraisal: A comparison of modern approaches. *Journal of Property Research, 30*(4), 239-265.

McCulloch, W. S. and Pitts, W. (1943). A logical calculus of the ideas immanent in nervous activity. *The Bulletin of Mathematical Biophysics, 5*(4), 115-133.

McGreal, S., Adair, A., McBurney, D. and Patterson, D. (1998). Neural networks: The prediction of residential values. *Journal of Property Valuation and Investment, 16*(1), 57-70.

Mimis, A., Rovolis, A. and Stamou, M. (2013). Property valuation with artificial neural network: The case of Athens. *Journal of Property Research, 30*(2), 128-143.

Mooya, M. M. (2015). The education and professional practice of valuers in South Africa: A critical review. *Property Management, 33*(3), 245 - 274.

Mora-Esperanza, J. G. (2004). Artificial intelligence applied to real estate valuation: An example for the appraisal of Madrid. *CATASTRO, April*(1), 255-265.

Morano, P., Tajani, F. and Torre, C. M. (2015). Artificial intelligence in property valuations An application of artificial neural networks to housing appraisal. from Advances in Environmental Science and Energy Planning http://www.wseas.us/e-library/conferences/2015/Tenerife/ENVIR/ENVIR-02.pdf

Mulrow, C. D. (1994). Rationale for systematic reviews. *British Medical Journal, 309*(6954), 597.

Oduwole, H. and Eze, H. (2013). A hedonic pricing model on factors that influence residential apartment rent in Abuja satellite towns. *Mathematical Theory and Modeling, 3*(12), 65-73.

Owusu-Ansah, A. (2012). Examination of the determinants of housing values in urban Ghana and implications for policy makers. *Journal of African Real Estate Research, 2*(1), 58-85.

Pagourtzi, E., Metaxiotis, K., Nikolopoulos, K., Giannelos, K. and Assimakopoulos, V. (2007). Real estate valuation with artificial intelligence approaches. *International Journal of Intelligent Systems Technologies and Applications, 2*(1), 50-57.

Paliwal, M. and Kumar, U. A. (2009). Neural networks and statistical techniques: A review of applications. *Expert Systems with Applications, 36*(1), 2-17.

Paris, S. D. (2008). *Using artificial neural networks to forecast changes in national and regional price indices for the UK residential property market.* (Doctoral disseration), University of Glamorgan, Wales, UK.

Ramsden, P. (1994). Describing and explaining research productivity. *Higher Education, 28*(2), 207-226.

Rossini, P. (1997). Artificial neural networks versus multiple regression in the valuation of residential property. *Australian Land Economics Review, 3*(1), 1-12.

Selim, H. (2009). Determinants of house prices in Turkey: Hedonic regression versus artificial neural network. *Expert Systems with Applications, 36*(2), 2843-2852.

Shapiro, E., Mackmin, D. and Sams, G. (2012). *Modern methods of valuation* (11th ed.). London: Estates Gazette.

Sibanda, W. and Pretorius, P. (2012). Artificial neural networks-a review of applications of neural networks in the modeling of HIV epidemic. *International Journal of Computer Applications, 44*(16), 1-9.

Sirmans, C. and Worzala, E. (2003). International direct real estate investment: A review of the literature. *Urban Studies, 40*(5-6), 1081-1114.

Taffese, W. Z. (2006). *A survey on application of artificial intelligence in real estate industry*. Paper presented at the 3rd International Conference on Artificial Intelligence in Engineering and Technology, Kota Kinabalu, Malaysia.

Taffese, W. Z. (2007). *Case-based reasoning and neural networks for real estate valuation.* Paper presented at the 25th IASTED International Milti-Conference, Artificial Intelligence and Applications, Innsbruck, Austria.12 - 14 February.

Tay, D. P. and Ho, D. K. (1992). Artificial intelligence and the mass appraisal of residential apartments. *Journal of Property Valuation and Investment, 10*(2), 525-540.

Tranfield, D., Denyer, D. and Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British Journal of Management, 14*(3), 207-222.

Tse, R. Y. (1997). An application of the ARIMA model to real-estate prices in Hong Kong. *Journal of Property Finance, 8*(2), 152-163.

Utkun, E. (2014). A review of literature about the use of artificial neural networks systems on prediction of clothing comfort. *Pamukkale University Journal of Engineering Sciences, 20*(7), 272-280.

Walters, L., Sietchiping, R. and Haile, S. (2011). *Land and property tax: A policy guide*. Nairobi,: United Nations Human Settlements Programme.

Ward. (1996). *Neuroshell 2 Manual*. United States: Ward Systems Group Inc.

Warren-Myers, G. (2015). Editorial, Journal of Property Investment & Finance. *Journal of Property Investment & Finance, 33*(2).

Waziri, B. S. (2010). *An artificial neural network model for predicting construction costs of institutional building projects in Nigeria.* Paper presented at the West Africa Built Environment Research (WABER) Conference, Accra, Ghana.27-28, July.

Wilson, I. D., Paris, S. D., Ware, J. A. and Jenkins, D. H. (2002). Residential property price time series forecasting with neural networks. *Knowledge-Based Systems, 15*(5), 335-341.

Witten, I. H. and Frank, E. (2005). *Data Mining: Practical machine learning tools and techniques* (Second ed.). San Francisco: Morgan Kaufmann.

Witten, R. G. (1987). Riding the real estate cycle. *Real Estate Today*, 42-48.

Wong, B. K., Bodnovich, T. A. and Selvi, Y. (1997). Neural network applications in business: A review and analysis of the literature (1988-95). *Decision Support Systems, 17*, 301-320.

Wong, B. K. and Selvi, Y. (1998). Neural network applications in finance: A review and analysis of literature (1990–1996). *Information & Management, 34*(3), 129-139.

Wong, K., So, A. T. and Hung, Y. (2002). Neural network vs. hedonic price model: Appraisal of high-density condominiums *Real Estate Valuation Theory* (pp. 181-198): Springer.

Worzala, E., Lenk, M. and Silva, A. (1995). An exploration of neural networks and its application to real estate valuation. *Journal of Real Estate Research, 10*(2), 185-201.

Xie, X. and Hu, G. (2007). *A comparison of Shanghai housing price index forecasting*. Paper presented at the 3rd International Conference on Natural Computation, Haikou.

Yacim, J. A. and Boshoff, D. G. (2014). *Mass appraisal of properties.* Paper presented at the 2nd Virtual Multidisciplinary Conference.15-19 December.

Yalpir, S. (2014). *Forecasting residential real estate values with AHP method and integrated GIS.* Paper presented at the People, Buildings and Environment Conference, an International Scientific Conference, Kroměříž, Czech Republic.15-17 October.

Yi, W. and Chan, A. P. (2013). Critical review of labor productivity research in construction journals. *Journal of Management in Engineering, 30*(2), 214-225.

Zhang, G., Patuwo, B. E. and Hu, M. Y. (1998). Forecasting with artificial neural networks: The state of the art. *International Journal of Forecasting, 14*(1), 35-62.

Zurada, J., Levitan, A. and Guan, J. (2011). A comparison of regression and artificial intelligence methods in a mass appraisal context. *Journal of Real Estate Research, 33*(3), 349-387.

Zurada, J. M., Levitan, A. S. and Guan, J. (2006). Non-conventional approaches to property value assessment. *Journal of Applied Business Research, 22*(3), 1-14.

About the authors

Rotimi Boluwatife Abidoye is a PhD candidate at the Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong. He is the corresponding author and can be contacted at: rotimi.abidoye@connect.polyu.hk

Albert P. C. Chan is a Chair Professor of Construction Engineering and Management and Head, Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong.