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VIRTUAL GO GREEN: CONFERENCE AND PUBLICATION

"Rethinking Built Environment: Towards a Sustainable Future"

Organiser:
Research, Industrial Linkages, Community & Alumni Network (PJIM&A)

Co-organiser:
Department of Built Environment Studies & Technology (JABT), Faculty of Architecture, Planning & Surveying (FSPU)

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Machine Learning Algorithms on Price and Rent Predictions in Real Estate: A Systematic Literature Review

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Abstract

Valuers face various challenges in determining property prices and rental values due to dependence on market data. Lack of data means lack of support for valuable contributions of property value attributes. The use of existing databases in property valuation assignments presents intrinsic challenges as the valuer could derive incorrect assumptions when analysing value-issued comparable data. The introduction and observation of the Machine Learning Model to solve unforeseen issues are timely in Industrial Revolution 4.0. It is part of the modern scientific methodology which offers an automated procedure for prediction and classification of circumstances. Malaysian real estate markets are yet to embrace machine learning techniques for property analysis. It is worth noting that when predicting property values and rentals, appraisers and investors cannot rely on historical market data from real estate transactions. To meet this requirement, certain computing techniques optimised for handling large amounts of data are the best options. This paper presents the machine learning algorithm applications on the prediction of property prices and rents in real estate. This study adapts a systematic literature review on features that influence office building rentals in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA). The systematic review findings suggest that Random Forest (RF), Decision Tree (DT), Linear Regression (LR), and Support Vector Machine (SVM), frequently utilise Machine Learning in price and rent predictions. This study will provide new insights on the Machine Learning Algorithms in the real estate industry.

Keywords: *Real Estate; Machine Learning; Price Predictions*; *Rent Predictions*

1.0 Introduction

In real estate studies, it is disappointing when predicting property prices and rentals, valuers and investors are unable to rely on market data analyses from real estate transactions over the time. This is a problem because accurate predictions of real property prices and rentals are critical for investors, developers, prospective owners, appraisers, tax assessors, and other real estate market stakeholders. As such, the industry needs a model in predicting the prices and rentals of property. There are a number of price prediction models in the real estate markets including the conventional method of rental growth estimation, econometric models, and machine learning models. Earlier techniques to calculate rental growth rates in discounted cash flow valuation exercises were sometimes excessively simple, resulting

in unrealistic predictions (Hendershott, 1996; Born & Pyhrr, 1994). Kummerow (1997) discovered that in the 1980s, Australian valuers frequently used a single, linear, and compounding rent increase rate in their evaluations. Prior research argued that the conventional approach in rental growth estimation is lacking in recognising the volatility of the real estate rental market. This could result in inaccuracy of estimation (Kummerow, 1999; Hendershott 1996; Born & Pyhrr, 1994). Additionally, recent studies also emphasized that only limited success can be achieved in finding a reliable and consistent model to predict property market movements over a five-to-ten-year time frame (Marcello Tonelli, Mervyn Cowley & Terry Boyd, 2018). Hence, the industry has to initiate discussions towards that goal while considering a reliable approach in predicting property prices and rentals. Computing techniques designed to handle big data, Machine Learning is the best choice. Hence, this study will identify the types of Machine Learning algorithms used in predicting property prices and rentals as the primary objective. Notably, there were numerous Machine Learning models implemented in prior studies relating to real estate. The types of Machine Learning models in real estate are yet to be revealed. Hence, this research determines the most frequently used Machine Learning models in real estate, specifically on price and rent predictions as the secondary objective.

2.0 Machine Learning

Machine Learning is defined as a computer system that allows direct learning from data specimen and experiences. It requires a reasonable understanding of research mechanisms, configurations, technique limitations, and properties to capture and interpret the data set (Kaytan & Aydilek, 2017). They are regarded as the workhorse of the so-called big data era (El Naqa & Murphy, 2015). Machine Learning methods are applied in various areas such as economic growth predictions, bankruptcy predictions, demand predictions, forecasting electricity prices, and price predictions in real estate markets (Er, 2018).

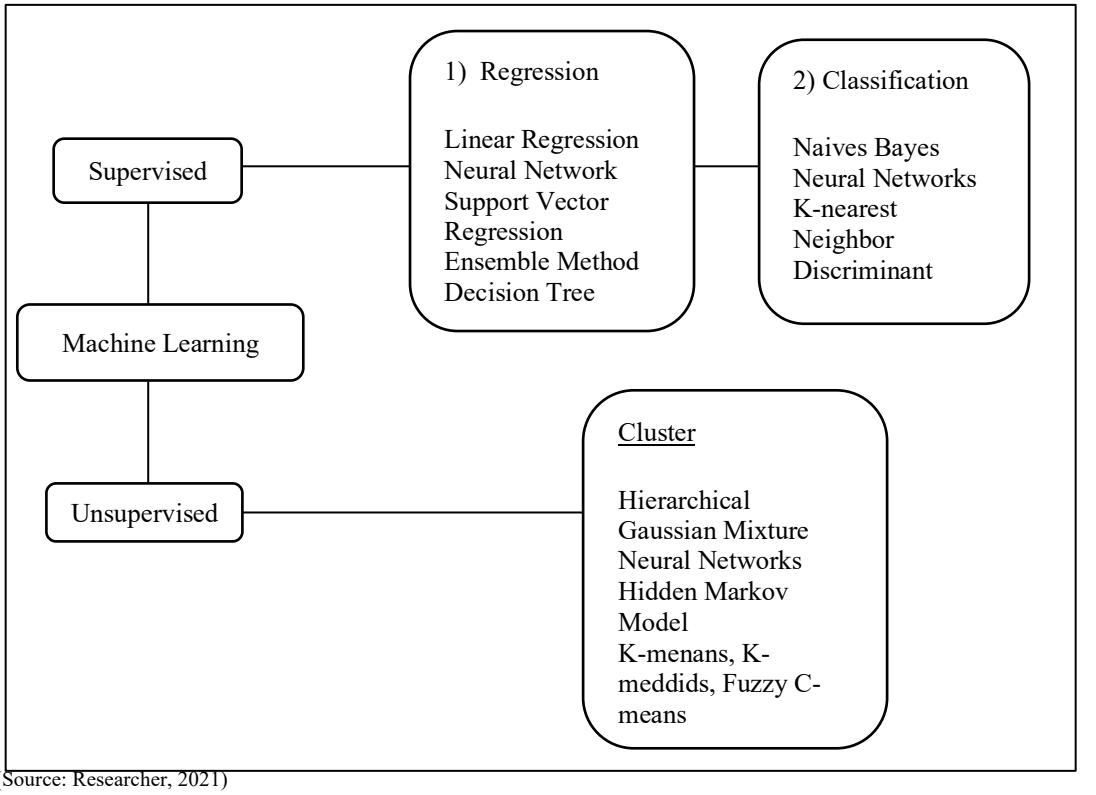
2.1 Machine Learning in Real Estate

Machine Learning Models are popular and influential in the Industrial Revolution 4.0 era. This is because they are frequently employed to address numerous prediction problems in a variety of industries including the real estate market. The expanding scope of the Industrial Revolution 4.0 has evolved into a central component of contemporary scientific methodology, providing an automated procedure for forecasting or prediction and classification of events. Machine learning has been used in a variety of research areas over the last decade and its versatility has attracted the use of the algorithms for a variety of applications. Recent studies have demonstrated that machine learning models are effective at predicting, estimating, and forecasting real estate sales, prices, and rentals including property selling prices (Baldominos et al., 2018), property rental prices (Zhou et al., 2019), and agricultural land values (Er, 2018). The accuracy of the Machine Learning Model output depends on a number of factors, including the researcher's selection, configuration, parameters, and techniques. Phan (2018) stated that the use of machine learning in the real estate market can be divided into two; the first is applied as trends in forecasting the house price index, and secondly in house price valuations. The authors use a vector autoregression model in predicting the house price index. The authors employ support vector machines in conducting house price valuations.

2.2 Machine Learning Model Group

Machine Learning is classified into two (2) types: supervised and unsupervised (Kaytan & Aydilek, 2017; Ng & Deisenroth, 2015). Ayodele (2010) defines supervised machine learning as an algorithm which creates a function to map the inputs to the desired outputs. The goal of supervised machine learning classification algorithms is to categorise data based on the prior knowledge. On the other hand, unsupervised learning is a category of algorithm which discovers patterns in unlabeled data. It is a machine learning algorithm that models a set of inputs when labeled examples are not available (Ayodele, 2010). The primary goal of unsupervised learning is to generate classification labels

automatically (Nasteski, 2017). These algorithms look for similarities between pieces of data to see if they could be grouped together. These groups are referred to as clusters and they represent a broad range of clustering machine learning techniques. The examples of unsupervised Machine Learning used in real estate modelling including hierarchical, gaussian mixture, neural network, hidden markov model and K-menans. Figure 1 illustrates more comprehensive Machine Learning model groups.



(Source: Researcher, 2021)

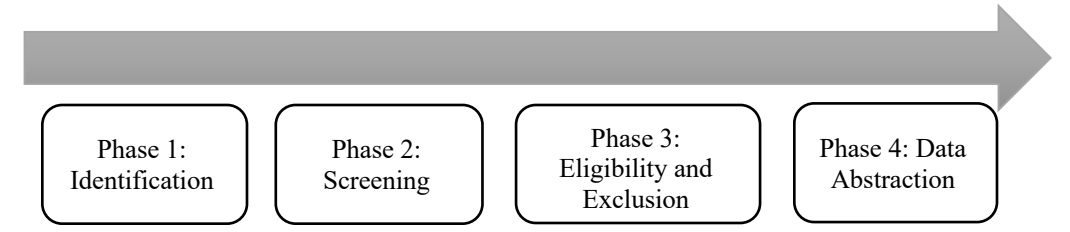
Figure 1. Machine Learning Model Groups

3.0 Methodology

The goal of a Systematic Literature Review (SLR) is to identify relevant primary articles, extract the necessary data, evaluate and synthesize findings to gain a deeper and broader understanding of the topic under research (Raymon et al., 2021). The strategy used to retrieve articles concerning Machine Learning algorithms on price and rent predictions in real estate is addressed in this section. This study implements the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) method which involves the utilization of online databases (Web of Science and Scopus) for the systematic reviews.

3.1 PRISMA

The review of the methodology involves four (4) steps in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) protocol. The steps involved are identification, screening, eligibility, data abstraction and analysis. According to Sierra-Correa & Kintz (2015), the Preferred Reporting Items for Systematic review and Meta-Analyses (PRISMA) provides three advantages; defines clear research questions that allow for systematic research, identifies the inclusive and exclusive criteria, and studies the wide scientific literature database in one time definition. Figure 2 presents the phases of SLR method used in this study.



(Source:(Shaffril et al., 2018)

Figure 2. Four (4) phases involved in SLR Method

3.2 Phase 1: Literature Identification

The literature was identified with a substantial search from established publication databases by including the related terms or topics related to Machine Learning applications in forecasting property prices and rentals. The systematic review was based on the two online databases (Scopus and Web of Science) which are accessible through https://ezaccess.library.uitm.edu.my/login. The literature items from the online databases were dated from 2009 to 2020. Related terms and keywords used in the search process are 'Machine Learning in Real Estate' and 'Machine Learning and price and rent predictions'. The search resulted in a total of 148 (62 from Web of Science; and 86 from Scopus) literature identifications with keywords mentioned in this section. After detailed screenings, 28 duplicated items were removed.

Table 1. Systematic Review Search Strings

No	Databases	Keywords
1	Scopus	**TITLE-ABS-KEY** (machine AND learning AND real AND estate AND price AND rent AND prediction)
2	Web of Science	**TOPIC:** (machine* learning* real* estate* price* rent* prediction*)

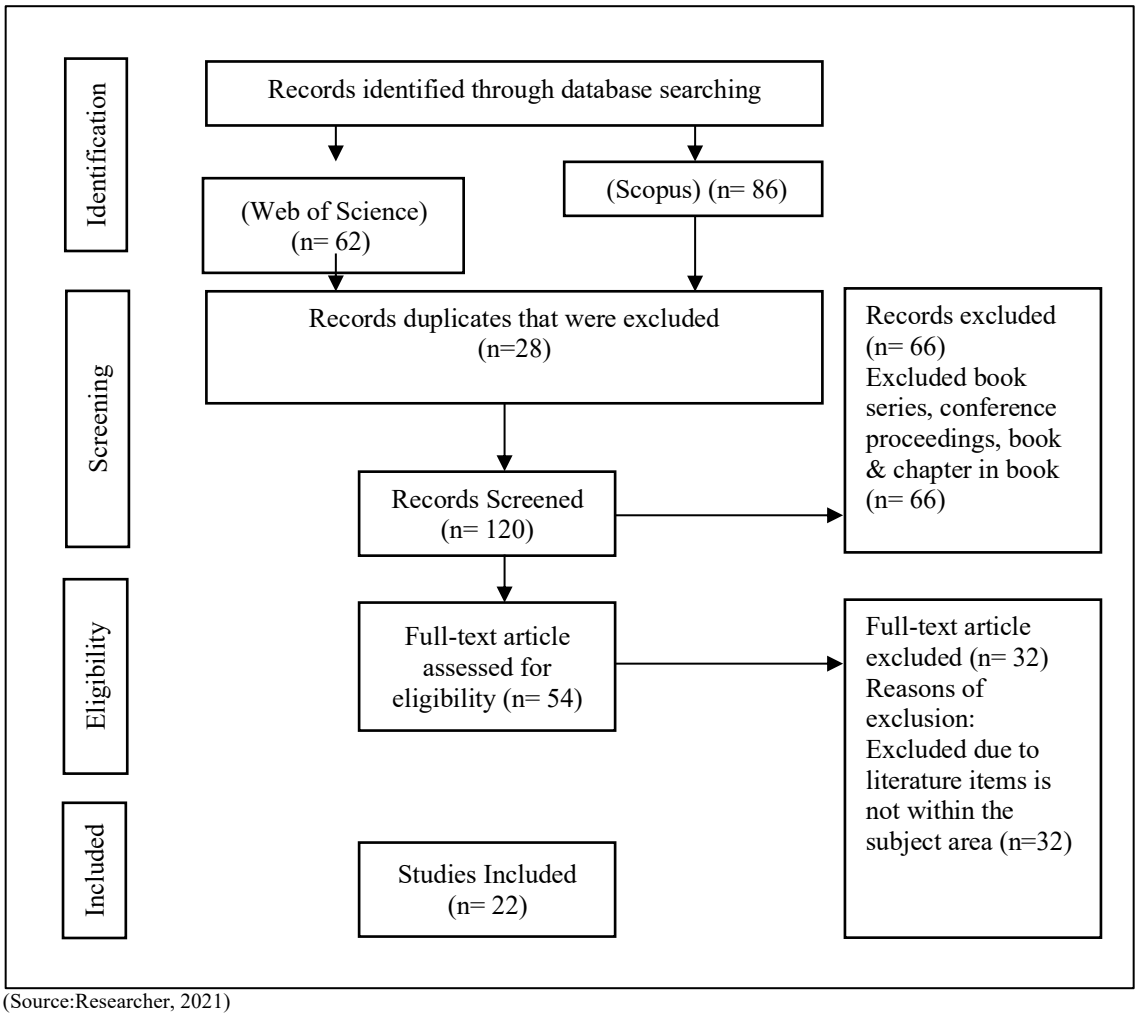
(Source: Researcher, 2021)

3.3 Phase 2: Literature Screening

The second phase involves literature screening to exclude 66 literature items. The reason for exclusion as some were identified as book series, conference proceedings, books, or chapters in books. Thus, 54 items are eligible to be assessed for the next phase.

3.4 Phase 3: Eligibility and Exclusion

The third phase comprises the eligibility assessment and exclusion to retrieve full articles for assessment. After a thorough examination, 32 literature items were removed as they do not focus on determining machine learning algorithms on price and rent predictions in real estate. As a result, only 22 items are eligible for this study.



(Source:Researcher, 2021)

Figure 3. Systematic Review Flow Diagram

Table 2. Machine Learning Algorithms & Applications in Real Estate Market Analysis

Authors/Publication Year	Machine Learning Model														Application	
	SVM	DT	RP	ADB	NB	LR	K-NN	GB	RF	NN	RD	LS	EN	LOR	Price Prediction	Rent Prediction
(McCluskey et al., 2014)		✓				✓			✓							✓
(Park & Bae, 2015)		✓	✓	✓	✓										✓	
(Oladunni & Sharma, 2016)		✓				✓	✓			✓					✓	
(Barr et al., 2017)		✓						✓							✓	
(Gu & Xu, 2017)								✓							✓	
(Baldominos et al., 2018)	✓						✓			✓					✓	
(Čeh et al., 2018)									✓						✓	
(Ma et al., 2018)		✓				✓		✓	✓							✓
(Dimopoulos & Bakas, 2019)						✓			✓							✓
(Huang, 2019)		✓				✓			✓						✓	
(Zhou et al., 2019)	✓	✓				✓	✓				✓	✓	✓			✓
(Guo et al., 2020)									✓						✓	
(Levantesi & Piscopo, 2020)									✓						✓	
(Modi et al., 2020)	✓				✓		✓							✓	✓	
(Pai & Wang, 2020)		✓								✓					✓	
(Pérez-Rave et al., 2020)		✓				✓			✓						✓	
(Shokoohyar et al., 2020)	✓				✓		✓		✓	✓				✓		✓
(Xue et al., 2020)		✓							✓						✓	
(Zulkifley et al., 2020)	✓							✓		✓					✓	
(Anysz et al., 2021)						✓									✓	
(E. Simlai, 2021)											✓	✓	✓		✓	
(Li et al., 2021)								✓							✓	
F(Total)	6	9	1	1	3	8	5	5	10	5	2	2	2	2	17	5

(Source:Researcher, 2021)

NB=Naïve Bayesian NN=Neural Network
SVM=Support Vector Machine LR=Linear Regression RD=Ridge
DT-Decision Tree K-NN=K-nearest neighbor LS=Lasso
RP=RIPPER GB=Gradient Boosting EN=Elastic Net
ADB=Adapting Boosting RF=Random Forest LOR=Logistic Regression

3.5 Phase 4: Data Abstraction

After completing all the required phases in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA), the last phase is data abstraction. The findings on the frequently used machine learning algorithms in real estate and its focus on price and rent predictions are reduced from fourteen to four. Random Forest, Decision Tree, Linear Regression and Support Vector Machine are among machine learning algorithms that will be included in the systematic review findings. The mostly used Machine Learning algorithms in real estate analysis and the applications of the algorithms in price and rent predictions in real estate are indicated in Table 2. The suggested algorithms will be explained in Section 4.0.

4.0 Machine Learning Algorithms in Price and Rent Findings

The suggested Machine Learning based on the most frequent Machine Learning algorithm used in price and rent predictions are illustrated in Table 3.

Table 3. Suggested Machine Learning

Suggested ML	(f) of ML in PP	(f) of ML in RP
Random Forest	(f= 6)	(f= 4)
Decision Tree	(f= 7)	(f= 2)
Linear Regression	(f= 4)	(f= 4)
Support Vector Machine	(f= 4)	(f= 3)
ML= Machine Learning	PP= Price Prediction	
RP= Rent Prediction		

(Source:Researcher, 2021)

4.1 Random Forest (RF)

The Random Forest algorithm is a supervised learning technique that could be used for classification and regression problems. It is a hybrid approach that uses Decision Trees as foundation learners. Random Forest is frequently used in real estate analysis specifically as a model in price and rent predictions. Numerous studies demonstrated that predictions obtained when using the Random Forest method can significantly improve prediction accuracy which confirms the potential of this Machine Learning technique for price predictions (Čeh et al., 2018; Jui et al., 2020; Levantesi & Piscopo, 2020; Xue et al., 2020)

Table 3 shows the frequency when the Random Forest (RF) algorithm is used as a model in real estate analysis. RF (f= 10) has the highest score out of 22 studies indicating it is the mostly used Machine Learning technique for real estate analysis based on the literature. Based on the ten studies that demonstrate the application of RF as a model in real estate analysis, (f= 6) studies discuss the application of RF as a price prediction model, while (f= 4) studies suggest the application of RF as a model in rent prediction.

4.2 Decision Tree (DT)

A Decision Tree is an extremely useful tool for the description, classification, regression, and prediction of data which is constructed using a process known as recursive partitioning (Fan et al., 2006). The goal of the Decision Tree algorithm is to build a model on the value of a target variable. To accomplish this, the Decision Tree employs a tree representation in which the leaf node corresponds to a class label and the inner node represents the attributes. DT is one of the ML that is frequently used in real estate studies as a price prediction model (Barr et al., 2017; Oladunni & Sharma, 2016; Park & Bae, 2015) and rent prediction (Dimopoulos & Bakas, 2019; McCluskey et al., 2014).

Table 3 shows the frequency when the Decision Tree (DT) algorithm is used as a model in real estate analysis with (f= 9) from a total of 22 studies. Based on nine (9) studies that demonstrate the application of DT as a model in real estate analysis, (f= 7) studies discuss the application of DT as a price prediction model, while the other (f= 2) studies suggest the application of DT as a model in rent predictions.

4.3 Linear Regression (LR)

The frequency when the Linear Regression (LR) algorithm is used as a model in real estate analysis is shown in Table 3. According to the literature, LR (f= 8) as a price and rent prediction model has been implemented in eight studies. Eight studies mentioned demonstrate the use of LR as a model in real estate analysis, four studies (f= 4) discuss the use of LR as a price prediction model, while the remaining four studies (f= 4) suggest the use of LR as a rent prediction model.

Linear Regression is a fundamental and widely used technique for predictive analysis. Hence, LR can be used as a model in predicting property prices and rents. However, previous studies proved the application of LR in price predictions does not provide a good result. This is because linear models are not predictive for complex home value data sets (Huang, 2019) as compared to non-linear. One of the shortcomings of traditional regression models is the requirement to specify the functional form of the model a priori and to account for all non-linearities (McCluskey et al., 2014).

4.4 Support Vector Machine (SVM)

The Support Vector Machine is a type of Machine Learning method based on the principle of structure risk minimization. By taking into account the characteristics of the data set, Support Vector Machine can be used to forecast real estate prices with high dimension, non-linear and small sample features (Wang et al., 2014), to determine rental strategy (Shokoohyar et al., 2020) and to predict price (Zulkifley et al., 2020).

Table 3 shows the frequency when the Support Vector Machine (SVM) algorithm is used as a model in real estate analysis. SVM (f= 6) indicates among the included studies, six studies used the SVM algorithm in analysing real estate data (Baldominos et al., 2018; Modi et al., 2020; Zhou et al., 2019; Zulkifley et al., 2020). Based on the six studies that demonstrate the application of SVM as a model in real estate analysis, (f= 3) studies discuss the application of SVM as a price prediction model while the other (f= 3) studies suggest the application of SVM as a model in rent prediction.

5.0 Conclusion and Recommendation

The systematic review findings discovered 14 Machine Learning Models in real estate study focusing on price and rent predictions. The types of models discovered were identified from the prior studies in the online databases. By identifying the models based on research evolution and related publications over the last eleven years that involved the investors, developers, prospective owners, appraisers, tax assessors, and other real estate markets, the stakeholders can predict real property prices and rentals more accurately. Out of the fourteen Machine Learning models discovered in the literature, some models are still not widely used in real estate data analysis such as the Elastic Net (EN), RIPPER (RP) and Adaptive Boosting (ADB) models.

The systematic review findings highlight the suggested ML to be implemented in price and rent predictions including Random Forest (RF), Decision Tree (DT), Linear Regression (LR) and Support Vector Machine (SVM). The selection is based on the frequency of the model being used in the real estate studies. The suggested models can be employed by the investors, developers, prospective owners, appraisers, tax assessors, real estate market stakeholders and researchers.

Future research should emphasize Machine Learning algorithms in the real estate industry and not just focusing on rent and price predictions. This study would like to propose research on price and rent forecasting rather than prediction by utilizing a Machine Learning algorithm as a model for real estate data analysis as provided in this systematic review as a research gap.

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