Penerbit Akademia Baru

Journal of Advanced Research Design

Journal homepage:
https://akademiabaru.com/submit/index.php/ard
ISSN: 2289-7984

Analyzing Criteria for Potential Adaptive Reuse of Pre-War Shophouses: A Multiple Linear Regression Approach

Nur Ain Ebas[1,*], Azeanita Suratkon[1], Nurul Shakira Ramlan[1], Muhamad Shahril Mohd Abdullah[1], Muhammad Ammar Shafi[2], Mohd Saifullah Rusiman[3], Efendi Nasibov[4]

[1] Department of Civil Engineering, Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn, Malaysia
[2] Department of Technology Management and Business, Universiti Tun Hussein Onn, Malaysia
[3] Department of Mathematics and Statistics, Faculty of Applied Sciences and Technology, Universiti Tun Hussein Onn, Malaysia
[4] Department of Computer Science, Faculty of Science, Dokuz Eylul University, Izmir, Turkiye

ARTICLE INFO

Article history:
Received 6 January 2025
Received in revised form 17 February 2025
Accepted 23 May 2025
Available online 2 June 2025

Keywords:
Adaptive reuse; pre-war shophouse; criteria; multiple linear regression

ABSTRACT

Pre-war shophouses are among the national historic structures that needs conservation work. However, choosing between adaptive reuse and other options is difficult because of the numerous factors involved. Therefore, before selecting a potential adaptive reuse, the adaptive reuse criteria must be taken into account. The criteria for adaptive reuse include six major categories: economic, environmental, social, architectural, technological, and legislative. These criteria represent as independent variables meanwhile the potential adaptive reuse represent as dependent variable. In this study, a specific group of respondents such as town planners from local governments, valuers from the valuation and Property Service Department (JPPH), architectural firms, researchers, and building owners who are involved in the adaptive reuse of pre-war shophouse buildings were given the questionnaire. In this work, multiple linear regression and descriptive statistics were used to analyze the data. In order to determine whether the shophouse can be reused rather than demolished and replaced by new structures, this paper applies multiple linear regression to analyze the relationship between the criteria for potential adaptive reuse. In other words, the study will identify the crucial conditions for potential adaptive reuse for a chosen new use of pre-war shophouses. The results show the new shophouse and the criteria for adaptive reuse have strong correlation.

1. Introduction

Adaptive reuse of prewar shophouses is a common approach to preserve heritage buildings and give them new purposes. It involves repurposing old buildings for active or passive use, such as cafes, boutique hotels, art galleries, community libraries and museums. According to Toong and Uberta [1], adaptive reuse criteria for prewar shophouses include the preservation of heritage buildings with minimal intervention, the use of appropriate materials, and the application of the right approach. Said *et al.,* [2] mentioned the adaptive reuse is increasingly becoming a more common approach in

* *Corresponding author*
E-mail address: nuraine@uthm.edu.my

https://doi.org/10.37934/ard.133.1.2232

order to preserve heritage buildings by discovering new purposes and used for the buildings. By referring to Yung *et al.,* [3], adaptive reuse is a technique that can be used to revitalize abandoned or ineffective pre-war shophouses so that they can be used for different purposes or transform it to a new use, aiding in the preservation of pre-war shophouses and their historical benefits. Architects, urban designers, and town-planners play a crucial role in shaping the city image through adaptive reuse projects. The physical changes and social impacts of adaptive reuse initiatives on society are important considerations. According to Abdulhameed *et al.,* [4] the adaptive reuse of shophouses should aim to retain the original function of the buildings, while allowing for changes in business form and architectural design. Studies have been conducted on the physical changes and effects on society after adaptive reuse projects in Kuala Lumpur studied by Toong and Uberta [1] and George Town studied by Said *et al.,* [2]. The research findings studied by Abdulhameed *et al.,* [3] indicate that adaptive reuse projects should involve more social engagements and a wider variety of building typologies. Karam *et al.,* [5] evaluated the building performance of heritage shophouses adapted into budget hotels and highlighting the importance of sensitive design judgments and the preservation of natural elements for successful adaptive reuse. Johar *et al.,* [6] mentioned that the integration of adaptive reuse in city planning and the preservation of city image can contribute to the economic and social value of a community.

The purpose of this research is to create adaptive reuse standards which are in line with possible new applications that assist architects, governments, and building owners in initiating adaptive reuse projects using the Multiple Linear Regression (MLR) approach for pre-war shophouses. The contribution of this research is:

i. Employed the MLR approach to identify potential reuse alternatives and understand the relationship between criteria for adaptive reuse.
ii. Developed adaptive reuse standards aligned with potential new applications, aiding architects, governments, and building owners in initiating adaptive reuse projects.
iii. Utilized a thorough literature review to identify and categorize thirty-three criteria affecting the decision to adaptively reuse existing and historic structures.

This study focusses on identifying potential reuse alternatives, and applying MLR to understand the relationship between criteria for adaptive reuse. The scope involves applying the MLR method to predict high criteria for pre-war shophouses in Batu Pahat, Malaysia, considering variables related to economic, environmental, social, technological, legislative and architectural aspects.

1.1 Criteria for Adaptive Reuse

Iskandar Regional Development Authority (IRDA), have identified certain areas in Johor that should be revitalised because they have heritage value. There were 2886 pre-war shophouses in Johor registered in Property Service Management (JPPH) according to data published by Commercial Property Stock Table Q3 2023 [7]. The total number of pre-war shophouses in the districts of Johor, which include Batu Pahat, Johor Bahru, Kluang, Kota Tinggi, Kulai, Mersing, Muar, Pontian, Segamat and Tangkak. Muar reached the highest number of 710, followed by Batu Pahat with a total of 617 and Segamat with a total of 544 is displayed in Figure 1. This study is solely focused on Batu Pahat.

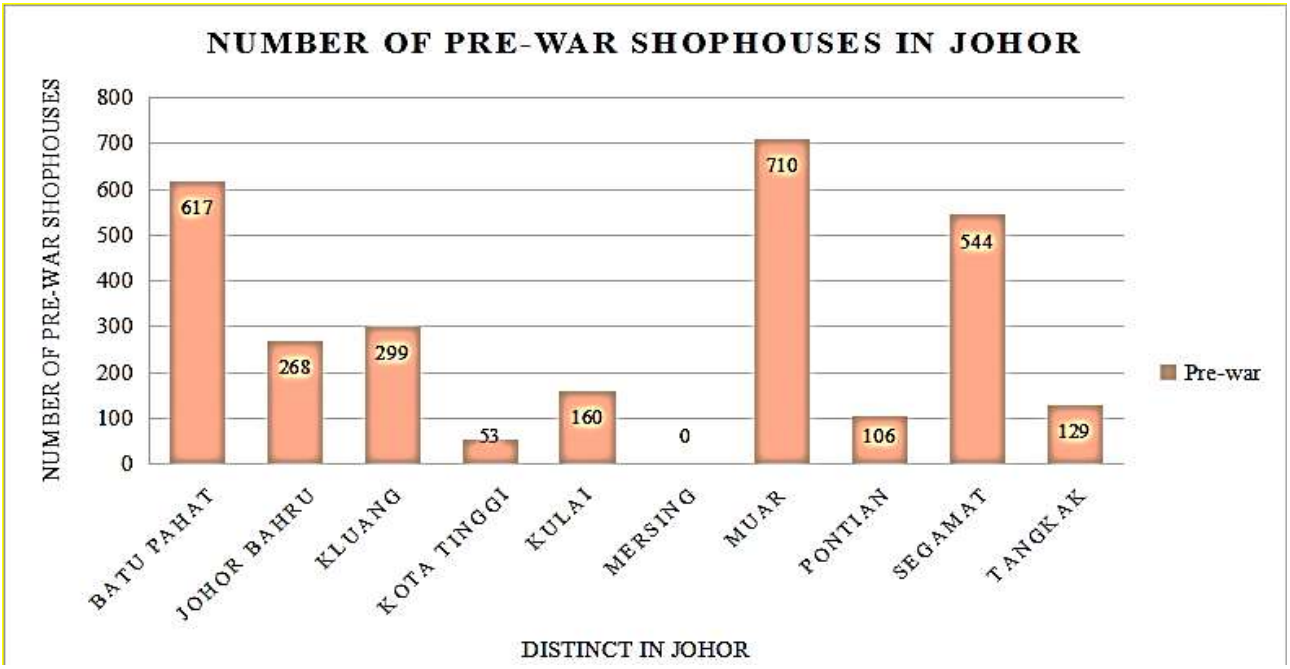

Fig. 1. Total number of pre-war shophouses in Johor by districts [7]

A thorough review of the literature was done to identify and determine the criteria that would affect the decision to adaptively reuse existing and historic structures. According to the most recent study by Mohd Abdullah *et al.,* [8], there are six broad parameters has been identified and categorized: economic, environmental, social, architectural, technological, and legal. This study focuses on thirty-three criteria, as indicated in Table 1.

Table 1
List of criteria categorised in six broad parameters [8]

Aspect	Criteria
Economic	Potential market
	Vacancy
	Financial and investment
	Subsidize and benefit of exemption
	Site amenities/ facilities
	Site amenities/ facilities
	Building value
	Building location
Environmental	Neighbourhood condition
	Scenic/ contextual value
	Environmental effect
	Reduce resource consumption
	Reduce use of greenfield sites
Social	Local's perception
	Social value
	Compatibility of newly introduced uses with existing
	Retaining a sense of place
	Enhancing the role of communities
Architectural	Architectural and physical condition
	Space gain and change
	Site layout
	Building suitability
	Building character

Technological	Renovation and maintenance
	Structural condition
	Building system/ technological value
	Building services
	Materials and decorations
Legislative	Regional development policies
	Official plan and zoning regulation
	Building code, regulation and heritage design requirement
	Condition of integrity and authenticity

It will be easy to determine a suitable adaptive reuse for transformation using these criteria. Sustainable urban development can be achieved by carefully planning and implementing adaptive reuse of these ancient commercial buildings in town centres, which can extend the life of the structures.

1.2 Potential of Adaptive Reuse in Prewar Shophouse

Shophouses built before World War II are usually owned by private individuals. In order to encourage private owners to restore their historic buildings especially shophouses in metropolitan areas, the government provides a variety of incentives. In order to enhance the quality of the environment, the government has built public restrooms, sidewalks, and several other amenities surrounding conservation zones. Shophouses are historically significant buildings with residential space upstairs and commercial space downstairs. There are fifteen examples of a potential adaptive reuse of pre-war shophouse in Malaysia that has been adaptively repurposed shown in Table 2.

Table 2
Prewar shophouse in Malaysia

No.	Potential adaptive reuse
1	Restaurant
2	Pharmacy
3	Hotel
4	Bank
5	New shophouse
6	Gymnasium
7	Rental House
8	Meeting room
9	Mosque/ temple/ church
10	Mini museum
11	Office
12	Gallery
13	Mini theatre
14	Clinic
15	Private school

2. Methodology

This study focuses on the relationship between criteria for potential adaptive reuse to facilitate the stakeholders in decision making of reuse the pre-war shophouses by the potential adaptive reuse. The potential adaptive reuse is chosen based on the highest ranking among the respondents by analyze using descriptive statistics. Data for this study is gathered using a questionnaire as a research method. The survey form was created and developed using the variables from six (6) broad

parameters as prospective criterion. The questionnaire has three sections, and the survey questions were presented to the selected respondents using a Likert scale. A measuring scale from 1 to 5 was used to gauge the responses to the questions 1 represents as not suitable and 5 represent as most suitable. The following are questionnaire section:

Part 1: Demographic background
Part 2: Potential adaptive reuse
Part 3: Criteria for adaptive reuse

2.1 Multiple Linear Regression

Linear regression is the study of the relationship between independent and dependent variable. Simple linear regression gets its adjective “simple” because it concerns the study of only one predictor variable. The term "multiple" in the name of MLR refers to the fact that it involves the analysis of two or more predictor variables (independent variables). The aim of multiple regression is to estimate the coefficients of the independent variables that best fit the data and can be used to make predictions or test hypotheses. Slinker *et al.,* [9] mentioned that MLR is a versatile tool that can be used to describe relationships, predict future outcomes, and identify outliers that may affect the model's performance. Table 3 represents the explanation of variables that is implemented in this study.

Table 3
Explanation of variables

Variable	Variable name
y	Potential adaptive reuse (New shophouse)
x_1	Economy
x_2	Social
x_3	Technology
x_4	Environment
x_5	Legislative
x_6	Architecture

Osborne *et al.,* [10] introduced the multiple linear regression model can be stated in Eq. (1):

$$Y_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \cdots + \beta_j X_{ij} + \varepsilon \quad (1)$$

Where, Y_i is dependent variable, $\beta_0, \beta_1, \beta_2, \beta_j$ are constants and $X_{i1} \ldots X_{ij}$ are unknown parameters/ independent variables. According to Vardopoulos *et al.,* [11], MLR is a statistical method used in the study of adaptive reuse. This approach allows for the identification of the factors that contribute to the practice of adaptive reuse and sustainable-driven developments in the built environment [12]. By applying multiple linear regression analysis, decision-makers and stakeholders can make well-informed decisions and achieve successful sustainable adaptations [13].

2.1.1 Assumption of multiple linear regression

Kunter *et al.,* [14] mentioned that before the regression model could be implemented, the assumptions of the model need to take into consideration and should be fulfilled. Brant *et al.,* [15] were characterized the assumptions of multiple linear regression model as below:

i. The predictor variables, x have a linear relationship with the response variable, y.
ii. The y observations were assumed to be statistically independent.
iii. The standard deviation of y within particular x-strata was constant over all values of x known as a homoscedasticity.
iv. The distribution of y within x-strata was normal.

In simple words, there are four assumptions of multiple linear regression that should be fulfilled before using the data for analysis which are linearity, homoscedasticity, multicollinearity and normality [16-19]. When these assumptions meet, the results will be trustworthy. Few articles reported that they rely on the tested assumptions of the statistical test to draw their conclusions. Basically, the residual analysis was used to ensure that the data are normally distributed (homoscedasticity and linearity). The plot is used to check its residual versus predicted value. Moreover, there is another plot that can be used to check the normality of data such as quartile-quartile plot (QQ-plot) or probability-probability plot (PP-plot). If the plot does not show any pattern or shape such as a U-shape or S-shape and shows randomly scattered, then the data are normally distributed. Multicollinearity diagnostic should be done to the data to avoid dependency among independent variables. The test used is the variation inflation factor (VIF). A serious multicollinearity problem exists if the VIF is more than 10. If the value of VIF is below 10, then the multicollinearity checking is satisfied [20].

3. Results

This section discusses the results obtained from descriptive analysis and MLR.

3.1 Descriptive Analysis

In this section, potential adaptive reuse is rank by the value of mean as shown in Table 4. Mean value is rank based on the highest mean value to the lowest mean value. Based on the results, only the highest mean value is analysed in order to examine the relationship between criteria and the potential adaptive reuse. The relationship between the variables is discussed in the next sub section.

Table 4
Mean value for potential adaptive reuse

Potential Adaptive Reuse	Rank	Mean		Std. Deviation
		Statistic	Std. Error	Statistic
New shophouse	1	4.4880	0.0511	0.6582
Restaurant	2	4.4699	0.0545	0.7022
Hotel	3	4.3072	0.0703	0.9056
Rental House	6	4.0301	0.0607	0.7818
Mosque	14	2.4880	0.0714	0.9194
gallery	11	3.2771	0.0698	0.8987
clinic	8	3.7952	0.0686	0.8843
pharmacy	4	4.1566	0.0651	0.8382
bank	13	2.5482	0.0772	0.9943
gymnasium	15	2.4217	0.0680	0.8755
office	5	4.0723	0.0637	0.8207
Mini museum	10	3.3614	0.0690	0.8887
Theatre hall	12	2.9880	0.0651	0.8384
Private school	7	3.9578	0.0776	0.9991
Meeting room	9	3.3795	0.0676	0.8707

Table 4 shows that the new shophouse, which ranks first, has the highest mean value for potential adaptive reuse which is 4.4880. In order to investigate the relationship between potential adaptive reuse and the criteria, the new shophouse is chosen as a dependent variable, while the criteria for adaptive reuse are independent variables.

3.2 Multiple Linear Regression

Basically, the assumptions have to be satisfied before utilizing the multiple linear regression. First assumption the residual of normality tested by P-P plot. The result of P-P plot in Figure 2 shows the data is somehow straight line. It proves the normality assumption satisfied.

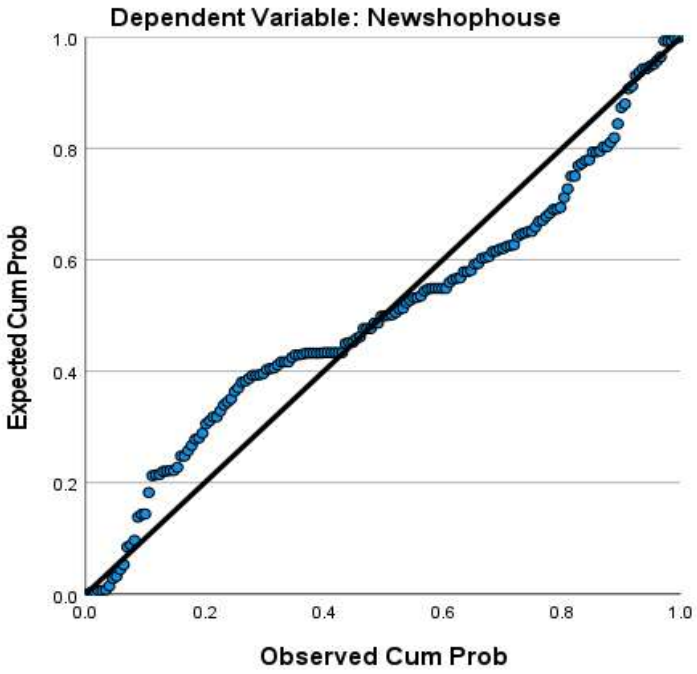

Fig. 2. Normal P-P plot of regression standardized residual

Second assumption is homoscedasticity and linearity. Figure 3 shows that residuals appeared to be randomly scattered and shows no pattern and assuming that the error terms have a mean of zero. This plot can be assumed that the variance in the error terms is constant. This assumption is satisfied.

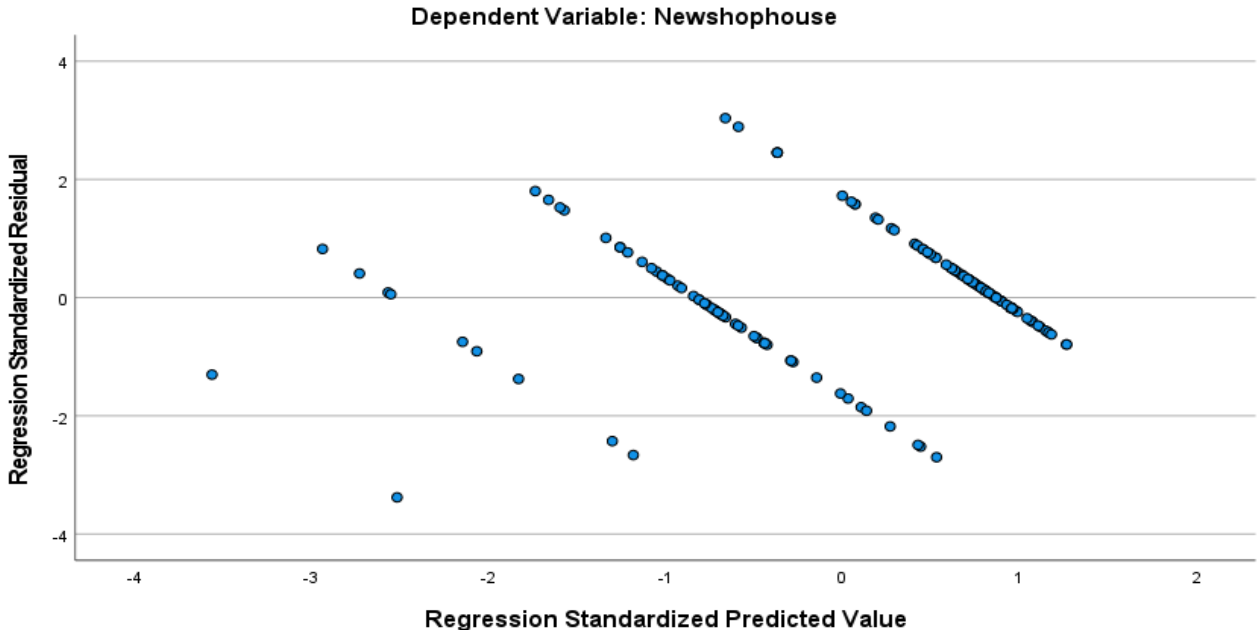

Fig. 3. Scatterplot variance of residual

Next assumption is multicollinearity. Based on the Table 5, all variables have relatively low tolerance values, ranging from 0.067 to 0.095. This indicates a relatively high degree of collinearity among the independent variables. Additionally, the VIF values are all above 10, with some exceeding 20, which further suggests multicollinearity issues in the model. The eigen values from top decreased to bottom value. It seems to provide a measure of the variability of each individual variable. The value of condition index is 46.578 which is below 1000. This indicated that no significant correlations exist between all independent variables and assumption of multicollinearity is satisfied.

Table 5
Collinearity statistics

Variables	Eigenvalue	Condition Index	Tolerance	VIF
Constant	6.943	1.000		
Economy	0.039	13.377	0.067	14.867
Social	0.010	26.166	0.042	23.783
Environment	0.003	46.578	0.091	11.047
Technology	0.002	59.163	0.095	10.533
Legislative	0.002	67.761	0.093	10.796
Architecture	0.001	81.576	0.081	12.320

Table 6 shows the parameter of MLR model. Based on the Table 6, the dependent variables, new shophouse has directly proportional to all independent variable except for legislative which is inversely proportional. Only two variable is significant which is legislative and architecture because significant level is less than 0.05 and that give the effect to dependent variables.

In order to determine if there are outliers in the dataset, the standardized residuals, studentized residuals, and Cook's distance is examined. Outliers typically have standardized or studentized residuals with absolute values significantly larger than 2 or Cook's distance values significantly larger than 1. Table 7 shows the residual statics including Mahalanobis and Cook’s distance.

Table 6
Parameter of MLR model

Variables	Standardized Coefficients Beta	Sig.
Constant		
Economy	0.065	0.124
Social	0.004	0.631
Environment	0.212	0.980
Technology	0.287	0.072
Legislative	-0.377	0.013
Architecture	0.666	0.001

Table 7
The residual statics including Mahalanobis and Cook's distance

	Minimum	Maximum	Mean	Std. Deviation
Predicted Value	2.387	5.235	4.488	0.590
Residual	-1.004	0.902	0.000	0.292
Std. Residual	-3.379	3.038	0.000	0.982
Stud. Residual	-3.554	3.076	-0.003	1.007
Stud. Deleted Residual	-3.692	3.162	-0.003	1.021
Mahal. Distance	1.081	26.384	5.964	4.260
Cook's Distance	0.000	0.192	0.008	0.022
Centered Leverage Value	0.007	0.160	0.036	0.026

Based on data in Table 7, there are no clear outliers in the dataset. The standardized and studentized residuals are within the typical range, and Cook's distance values are all below the threshold for identifying influential points.

This study finds the correlation value between the dependent variable and each independent variables using SPSS software. If the value of correlation is close to 1 meaning that the relationship is strong. All independent variables have strong correlation values towards the dependent variable which is greater than 0.5. The highest correlation value is 0.866 which is the correlation between new shophouse and architecture. Table 8 shows the correlation among the dependent variable and independent variables. The R-square value is 0.804 indicates the 80.4% of the variation in the response variable Y that is explained by the variation in the predictor variable X.

Table 8
Correlation

	New shophouse	Economy	Social	Environmental	Technological	Legislative	Architecture
New shophouse	1.000	0.793	0.792	0.834	0.851	0.661	0.866
Economy	0.793	1.000	0.938	0.879	0.902	0.912	0.935
Social	0.792	0.938	1.000	0.929	0.911	0.933	0.931
Environmental	0.834	0.879	0.929	1.000	0.927	0.831	0.913
Technologicl	0.851	0.902	0.911	0.927	1.000	0.807	0.914
Legislative	0.661	0.912	0.933	0.831	0.807	1.000	0.851
Architecture	0.866	0.935	0.931	0.913	0.914	0.851	1.000

4. Conclusions

In conclusion, pre-war shophouses exhibit considerable national heritage significance, warranting their preservation, particularly through adaptive reuse to promote sustainable practices by circumventing unnecessary demolition and reconstruction. Nevertheless, the decision-making procedure for adaptive reuse is complex, and being influenced by many factors. This research undertook a survey through questionnaires involving stakeholders including town planners, valuers,

architects, researchers, and building owners, pinpointing new shophouse as a potential adaptive reuse. There are thirty-three criteria which categorize into six categories which are Economic, Environment, Social, Technology, Legislative, and Architecture. The assumption of multiple linear regression has been met. Therefore, the analysis of the data was done using multiple linear regression. Furthermore, the study explores the correlation between criteria and adaptive reuse alternatives. From the analysis, the relationship between criteria and potential adaptive reuse is strong relationship where the R-square is 80.4%. All the correlation value between dependent variable (new shophouse) and independent variables are more than 0.5 indicates the strong correlation. The enhancement of its overall performance and predictive capability may be achieved through an exploration of varied modelling approaches, incorporation of additional variables, or enhancement of the existing model.

Acknowledgement
This research was supported by Universiti Tun Hussein Onn Malaysia (UTHM) through Tier 1 (Vot Q134).

References

[1] Toong, Yong Seng, and Nangkula Utaberta. "Kuala Lumpur Chinatown Pre-War Shophouses (Adaptive Re-Use) and City Image." *Applied Mechanics and Materials* 747 (2015): 40-43. https://doi.org/10.4028/www.scientific.net/AMM.747.40
[2] Said, Shahrul Yani, Hanis Zafia Abdul Hamid, and Jonny Wongso. "The Usersâ€™ Perceptions on Adaptive Reuse of Selected Heritage Shophouses in Jalan Tun HS Lee." *Environment-Behaviour Proceedings Journal* 7, no. 19 (2022): 249-254. https://doi.org/10.21834/ebpj.v7i19.3238
[3] Yung, Esther HK, and Edwin HW Chan. "Implementation challenges to the adaptive reuse of heritage buildings: Towards the goals of sustainable, low carbon cities." *Habitat international* 36, no. 3 (2012): 352-361. https://doi.org/10.1016/j.habitatint.2011.11.001
[4] Abdulhameed, N., M. J. Mamat, and S. A. Zakaria. "Adaptive reuse approaches of Shophouses at Cannon Street in George Town, Penang." In *IOP Conference Series: Materials Science and Engineering*, vol. 636, no. 1, p. 012014. IOP Publishing, 2019. https://doi.org/10.1088/1757-899X/636/1/012014
[5] Al-Obaidi, Karam M., Sim Li Wei, Muhammad Azzam Ismail, and Kenn Jhun Kam. "Sustainable building assessment of colonial shophouses after adaptive reuse in Kuala Lumpur." *Buildings* 7, no. 4 (2017): 87. https://doi.org/10.3390/buildings7040087
[6] Johara, Suhana, Tan Sherrona, and Noraziah Mohammada. "Penyesuai gunaan semula rumah kedai lama di Jalan Mendaling, Kajang-Satu tinjauan umum." *Jurnal Kejuruteraan* 5, no. 1 (2022): 111-121. https://doi.org/10.17576/jkukm-2022-si5(1)-12
[6] Konrath, Robert, Christian Klein, and Andreas Schröder. "PSP and PIV investigations on the VFE-2 configuration in sub-and transonic flow." *Aerospace Science and Technology* 24, no. 1 (2013): 22-31. https://doi.org/10.1016/j.ast.2012.09.003
[7] Aidan Technologies, “Visualisasi Data - NAPIC,” *NAPIC*, n.d.
[8] Abdullah, Muhamad Shahril Mohd, Azeanita Suratkon, and Syed Burhanuddin Hilmi Syed Mohamad. "Criteria for adaptive reuse of heritage shop houses towards sustainable urban development." *International Journal of Sustainable Construction Engineering and Technology* 11, no. 1 (2020): 42-52.
[9] Slinker, Bryan K., and Stanton A. Glantz. "Multiple linear regression: accounting for multiple simultaneous determinants of a continuous dependent variable." *Circulation* 117, no. 13 (2008): 1732-1737. https://doi.org/10.1161/CIRCULATIONAHA.106.654376
[10] Osborne, Jason W., and Elaine Waters. "Four assumptions of multiple regression that researchers should always test." *Practical assessment, research, and evaluation* 8, no. 1 (2002).
[11] Vardopoulos, Ioannis. "Adaptive reuse for sustainable development and land use: A multivariate linear regression analysis estimating key determinants of public perceptions." *Heritage* 6, no. 2 (2023): 809-828. https://doi.org/10.3390/heritage6020045
[12] Perrone, Valerio, Rodolphe Jenatton, Matthias Seeger, and Cedric Archambeau. "Multiple adaptive Bayesian linear regression for scalable Bayesian optimization with warm start." *arXiv preprint arXiv:1712.02902* (2017).

[13] Moon, Bochang, Jose A. Iglesias-Guitian, Sung-Eui Yoon, and Kenny Mitchell. "Adaptive rendering with linear predictions." *ACM Transactions on Graphics (TOG)* 34, no. 4 (2015): 1-11. https://doi.org/10.1145/2766992
[14] Kutner, M.H. and Nachtsheim, C. and Neter, J. 4th Ed. *Applied linear regression models* (McGraw-Hill/Irwin,2004)
[15] La Rocca, Maurizio, Tiziana La Rocca, and Alfio Cariola. "Capital structure decisions during a firm's life cycle." *Small Business Economics* 37 (2011): 107-130. https://doi.org/10.1007/s11187-009-9229-z
[16] Brand, Rhonda M., David D. Jones, Henry T. Lynch, Randall E. Brand, Patrice Watson, Ramesh Ashwathnayaran, and Hemant K. Roy. "Risk of colon cancer in hereditary non-polyposis colorectal cancer patients as predicted by fuzzy modeling: Influence of smoking." *World journal of gastroenterology: WJG* 12, no. 28 (2006): 4485. https://doi.org/10.3748/wjg.v12.i28.4485
[17] Jankovic, M. S. "The Multivariate Statistical Analysis–Multiple Linear Regression." *Int J Biomed Healthc* 10, no. 4 (2022): 253-255. https://doi.org/10.5455/ijbh.2022.10.173-175
[18] Alita, Debby, Ade Dwi Putra, and Dedi Darwis. "Analysis of classic assumption test and multiple linear regression coefficient test for employee structural office recommendation." *IJCCS (Indonesian Journal of Computing and Cybernetics Systems)* 15, no. 3 (2021): 295-306. https://doi.org/10.22146/ijccs.65586
[19] Samiyu, Mutiu. "Multiple Regression Model for predicting GDP using Macroeconomic variables (Part 1)." *Available at SSRN 3895177* (2021). https://doi.org/10.2139/ssrn.3895177
[20] Jobson, J. D., and J. D. Jobson. "Multiple linear regression." *Applied multivariate data analysis: Regression and experimental design* (1991): 219-398. https://doi.org/10.1007/978-1-4612-0955-3_4
[21] Shrestha, Noora. "Detecting multicollinearity in regression analysis." *American journal of applied mathematics and statistics* 8, no. 2 (2020): 39-42. https://doi.org/10.12691/ajams-8-2-1