SEM-PLS Analysis Approach in Identifying the Effective Residential Bikeway Design Factors

Mohd Zahid Mohd Salleh¹, Nurhayati Abdul Malek², Noriah Othman¹, Siti Zabella Mohammad²
¹Centre of Studies for Postgraduate Studies, Faculty of Architecture, Planning & Surveying, Universiti Teknologi MARA, 40450 Shah Alam, Malaysia.
²Centre of Studies for Landscape Architecture Faculty of Architecture, Planning & Surveying Universiti Teknologi MARA, Kampus Puncak Alam, 42300 Bandar Puncak Alam, Selangor, Malaysia.

Email: nurhayati.abdmalek@gmail.com

Abstract. The study was conducted to investigate the impact of residential-bike environment influences cycling participation among resident. The underpinning theories used in the study were the Ecological Model of Active Living (EMAF) and the Theory of Routine Mode Choice Decision (TRMCD). A structured questionnaire online survey was employed by engaging two resident associations (RA) in City of Elmina that contributed, 242 respondents. The data was analysed using Smart PLS 3.2.6 to test a developed model through measurement model analysis and followed by a structural model analysis. This approach offers comprehensive, quantifiable and flexible causal-modelling capabilities in a multi-regression analysis for non-parametric data that run simultaneously. The measurement model analysis was archived the threshold values for all criteria such as reliability and validity test. The structural model analysis result showed that perception, preference and satisfaction have significant positive relationship with the bike-built environment directly. Besides, the bike-built environment and cycling participation among resident has significant positive relationship. The Coefficient Determination, R² of the bike-built environment was substantial value with 33 percent while the cycling participation was 7.3 percent. The study confirmed that the residential-bike built environment has impact on the cycling participation among resident.

1. Introduction
Presently, the township development in Malaysia is accelerating transform towards wellness living concept that offers more green spaces and green infrastructure to pushed carbon emission remediation as well [1], [2]. An example, sustainable mobility like cycling is well promoted in keeping resident active in the urban area, and it is incarnating among Malaysian nowadays [3][4]. The support system such as an appropriate infrastructure endowment, integrated land use planning and robust education promotion are the key elements that need to be concentrated [5][6]. Unfortunately, we face some restriction such as infancy bike built environment that affects ridership in Malaysia [7]. Consequently, the understanding of the environmental behaviour towards cycling activity among Malaysian is a focus in the study. The study will develop a model to understand the relationship between the perceived physical environment that influence the bike-built environment as well as cycling participation promotion.

The model was fabricated from the underpinning theories such as the Ecological Model of Active Living (EMAF) and the Theory of Routine Mode Choice Decision (TRMCD). The EMAF is illustrated
that when people are motivated (perceived environment) and setting support (residential-bike built environment) would lead the high cycling participation [8][9]. Furthermore, three steps evaluation of perceived environment will enhance the understanding of cycling behaviour through the perception, preference and satisfaction that introduced by TRMCD. When the three essential elements (1. Safety/security; 2. Convenience & 3. Enjoyment) are archived, the people will be adopted the cycling mode practically and regularly in daily life [10]. Thus, the developed model as exhibited in Figure 1 is showed to understand the relationship between perceived perception (Safety-TRMCD), perceived preference (Convenience-TRMCD) and perceived satisfaction (Enjoyment-TRMCD) on the bike-built environment (Setting-TEMAF) towards cycling participation (Behaviour-TEMAF/TRMCD).

The study will evaluate the impact of residential-bike built environmental that force to environmental intervention (effective bikeway design) towards cycling promotion [11]–[14]. The perceived perception residential environment revealed by filtering the environmental information of surrounding to expose the critical factors that appropriate towards the behaviour. The perception of personal safety, crime, traffic, infrastructure availability, network system, public facilities, park and open spaces, climate and natural features have been significantly positive relationship towards cycling [16]–[18]. Therefore, the first hypothesis was established as follows: **H1- The perceived perception of residential environment has a positive effect on the bike-built environment.**

Moreover, the perceived preference of route choice is prioritising or choosing the specific elements of condition to fit their insight towards behaviour [18]. It is vital to explore due to understanding the interaction way of the individual with a set of distinctive values of the specific environment. The previous studies was focused on the characteristics of the road, traffic ambience, environment setting, trip purpose and the route character that has been affected the cycling activity [19]–[21]. Thus, the second hypothesis is **H2- The perceived preference of route choice has a positive effect on the bike-built environment.**

The cycling habit also affected by perceived satisfaction when all expectation and needs had been fulfilled. The evaluation operationalised with the circumstance on the roadway corridor environment that emphasised the width, traffic volume, activities, pavement and stoppages [22]–[24]. It shows that the satisfaction consideration will enhance the behaviour with some intervene effort from the evaluation. Besides, the maintenance, environment, network, design and personal satisfaction are the factors that need to be determined further [25]. Hence, the third hypothesis comes out such as **H3- The perceived satisfaction of travel environment has a positive effect on the bike-built environment.**

The bike built environment is the behavioural setting that serves people to do cycling in proper manner equivalently with other types of modes that need a specific system. The cycling-friendly cities have been proper layout planning, facilities, design methods, and detailed design that can be contemplated with some adjustment to suit Malaysia context [26]. Besides, the key aspect that has been stressed in the bike-built environment enhancement are coherence, directness, attractiveness, traffic

![Figure 1. Theoretical Research Model](image-url)
safety, comfort, and spatial integration [27]. All these elements will lead to the cycling participation among people when they assist with the good ambience of the cycling environment. Therefore, the final hypothesis developed is as follow: \textit{H4- The bike-built environment has a positive effect on cycling participation.}

2. Methodology
The City of Elmina, Selangor was the chosen site for the study conducted. We engaged with the residential association (RA) to distribute the survey link on the resident web pages. The minimum sample size of 92 respondents has been calculated at 80 per cent with effect size 0.15 using Daniel Soper Calculator [28]. However, the actual sample size should be exceeded 92 and the actual sample size will be discussed in 3.1 afterward. A structured questionnaire online survey is used with six segments including demographic profile (6 items), perception (5 items), preference (5 items), satisfaction (5 items), bike-built environment (6 items) and participation (3 items). The measurement level is comprised continues (a five-level Likert-scale with “Strongly Disagree” until Strongly Agree”) and definite measurement. Eventually, the analysis operationalised by using IBM SPSS version 23 and Smart PLS 3.2.6 to extract the significant statistical result. The rules of thumb consideration to applying Smart PLS can examine both reflective and formative measurement models and works precisely with small sample sizes, it does not require normal-distributed data, and importantly the study aims for theory confirmation proposition [29]. The process of analysis comprises two-stage procedures which are measurement model analysis (Reliability And Validity Test) and followed by a structural model analysis (Hypothesis Testing) [30]. Besides, a bootstrapping method subsequent with path coefficients and significant loadings value. This approach offers comprehensive, quantifiable and flexible causal-modelling capabilities in the multi-regression analysis for non-parametric data that run simultaneously [31].

3. Result
The PLS rules of thumb were occupied accordingly in the study. The small size data (n=242) was confirmed, and non-normal distributed data was proved by Mardia’s multivariate skewness and kurtosis test stated that ($\beta = 6.665$, $p< 0.01$) and ($\beta = 44.876$, $p > 0.01$) respectively above the cut-off value of skewness ±3 and kurtosis ±20 [30]. Thus, the non-parametric analysis software can be used for analysis purpose like Smart PLS.

3.1. Demographic Profile
It is confirmed that 242 respondents were employed. The study obtained information on gender is dominated by male (59.5%) compared to 40.5% are female. The respondent age ranged between 25 and 44 years old (47.6%) is prominent. Among them, the study identified 59.5% was led by Malay and followed by Chinese and Indian which were 21.4% and 19% respectively. This group of respondent entailed of diploma (26.2%), bachelor (40.5%) and higher bachelor degree (31%) holders. We found that the respondent had preferred to use private transport with 71.4% (Car) and 26.2% (Motorcycle). Surprisingly, 2.4% has been used as a bicycle as a transport mode in daily life.

3.2. Measurement Model Analysis

3.2.1. Construct and Convergent Validity
The measurement model analysis was examined the construct and convergent validity with threshold values (factor loadings, > 0.70; Cronbach Alpha (CA), > 0.70; Average Variance Extracted (AVE), > 0.50; and Composite Reliability (CR), > 0.70) [32] for reflective measurement model. As shown in Table 1, it was found that the individual items loadings were 0.496 – 0.948. Although two items stated as 0.496 and 0.634 it still useable due to the measurement threshold (AVE and CR) had met, thus, both indicators have remained. Consequently, CA reached above 0.70 threshold value with ranged between 0.717 to 0.864. The AVE values were above 0.50 (0.554 – 0.888) while CR were ranged from (0.827 – 0.936), above 0.70. For the formative measurement model does not have CR and AVE but it measured...
by weight loading with significant level t-values and collinearity assessment by evaluating variance inflation factors (VIF) with values less than 5.0 [30]. All the data were met the threshold value as per stated in Table 1 and Figure 2 (in Appendix A). So the measurement model analysis has met the requirement.

Table 1. The Convergent Validity of measurement Model Analysis Result

| Measure   | Construct     | Items | Loadings/Weight | Cronbach Alpha | CR/VIF | AVE/T-Value |
|-----------|---------------|-------|-----------------|----------------|--------|------------|
| Reflective | Perception    | PER4  | 0.750           | 0.717          | 0.827  | 0.554      |
|           |               | PER5  | 0.828           |                |        |            |
|           |               | PER8  | 0.496           |                |        |            |
|           |               | PER9  | 0.850           |                |        |            |
| Preference |               | PRE2  | 0.716           | 0.846          | 0.890  | 0.620      |
|           |               | PRE3  | 0.832           |                |        |            |
|           |               | PRE4  | 0.807           |                |        |            |
|           |               | PRE5  | 0.854           |                |        |            |
|           |               | PRE6  | 0.716           |                |        |            |
| Satisfaction |           | SAT2  | 0.634           | 0.743          | 0.840  | 0.570      |
|           |               | SAT3  | 0.796           |                |        |            |
|           |               | SAT4  | 0.737           |                |        |            |
|           |               | SAT5  | 0.838           |                |        |            |
| Participation |   | PART6 | 0.927           | 0.864          | 0.936  | 0.880      |
|           |               | PART7 | 0.948           |                |        |            |
| Formative | Bike Environment | BDF10 | 0.522           | 1.667          | 3.203  |            |
|           |               | BDF11 | 0.447           | 2.228          | 2.334  |            |
|           |               | BDF2  | 0.286           | 1.900          | 2.003  |            |
|           |               | BDF5  | -0.634          | 2.569          | 3.285  |            |
|           |               | BDF7  | 0.454           | 1.482          | 2.586  |            |
|           |               | BDF9  | -0.342          | 1.053          | 2.933  |            |

3.2.2. Discriminant Validity

Next, there are two approaches to assess the discriminate validity by using Fornell and Larcker’s (1981) criterion and Heterotrait-Monotrait Ratio of correlations (HTMT) by Henseler et al. (2015). For the study, we used the HTMT ratio as per Table 2; it stated that the constructs were confirmed the threshold value less the 0.90 [33].

Table 2. The Discriminant Validity of Measurement Model Analysis Result (HTMT Ratio)

|                  | 1    | 2    | 3    | 4    |
|------------------|------|------|------|------|
| Participation    |      |      |      |      |
| Perception       | 0.470|      |      |      |
| Preference       | 0.225| 0.137|      |      |
| Satisfaction     | 0.080| 0.567| 0.257|      |

3.3. Structural Model Analysis

Before we proceed with the structural model analysis, a model fit assessment need to be carried out by statistical inference bootstrapping called Standardized Root Mean Square Residual (SRMR). It used to escape the model misspecification with implying the values less than 0.10 [34], and the value of the study is 0.097 whereby it passed the threshold value.

3.3.1. Hypothesis Testing Result
The next stage is to proceed with the hypothesis testing by looking at path coefficient (β), standard error, t-values, collinearity, coefficient determination (R²), effect size (F) and predictive relevance (Q²) via performing a resample of 5,000 bootstrapping procedure [30]. Currently, the combination of statistical (p-value) and substantive significant (F) are vital information to be reported due to effect size is not revealed by p-value alone [35]. Subsequently, the quantitative reporting result should be included all elements that have been mentioned above with additional items comprises confidence interval and decision-theoretical modelling [36] as per Table 3.

Environmental Perception (β = 0.193, t = 3.023, p< 0.01, f² = 0.078), Environmental Preference (β = 0.405, t = 6.843, p< 0.01, f² = 0.232) and Environmental Satisfaction (β = 0.215, t = 3.376, p< 0.01, f² = 0.056) had influenced bike-built environment positively whereby 33.3% of R² (bike-built environment predictors) indicates substantial model with above 0.26 threshold value [37]. Thus, the hypothesis H1, H2 and H3 were supported. For instance, the predictive effects between bike-built environment and cycling participation were looked up next. Bike-built environment (β = 0.270, t = 3.023, p < 0.01, f² = 0.078) was significant predictor of cycling participation with only 7.2% of R² (cycling participation predictor) indicates weak model with above 0.02 threshold value [37]. However, the hypothesis H4 accepted to support. Afterward, the predictive relevance value also should have explained by using blindfolding procedure to obtain Q² value. It can be assessed for the reflective measurement model only and the value for the study was 0.057, more than zero value [30] as shown in the Table 3 and Figure 3 (in Appendix A).

4. Discussion and conclusion

The study was found the effective bikeway design factors via SEM-PLS analysis approach (statistical and substantive significant) through built environment evaluation. Initially, it is uncommonly used in the social, built environment study. However, the study tries to explore the significant application towards understanding the environmental behaviour by using developed model testing to obtain significant predictors. The environmental perception implicates that resident's perception of the convenience infrastructure, good street network system, acceptable climatic condition and pleasant natural setting have been influenced by the behavioural setting (bike-built environment). These items have similar findings from the previous study using the Neighbourhood Environment Walkability Scale (NEWS) [13]. It shows that perception is a fundamental awareness of the environment at a macro-scale level.

Moreover, the study reveals pavement types, dedicated space, security, proximate and scenic are the environmental preferences that need to emphasise in cycling ambience intervention. This prediction confirmed that preference has a most robust positive relationship among the other predictors. Thus, the preference takes action as a micro-scale level of evaluation before conducting cycling [19]–[21], [38], [39]. Environmental satisfaction also has a positive effect on the bike-built environment. The study associated with the fulfilment of expectation towards cycling in the residential neighbourhood. The

| Table 3. The Result of Hypothesis Testing (Structural Model Analysis) |
|---|---|---|---|---|---|---|---|---|
|   | Std. Beta | Std. Error | t-value | Decision | 2.50% | 97.50% | VIF | R² | Q² | F² |
| H1-Bike Environment -> Participation | 0.270 | 0.089 | 3.023** | Supported | -0.139 | 0.388 | 1.000 | 0.072 | 0.057 | 0.078 |
| H2-Perception -> Bike Environment | 0.193 | 0.084 | 2.296** | Supported | -0.114 | 0.323 | 1.188 | | 0.051 | |
| H3-Preference -> Bike Environment | 0.405 | 0.059 | 6.843** | Supported | 0.271 | 0.509 | 1.042 | | 0.232 | |
| H3-Satisfaction -> Bike Environment | 0.215 | 0.064 | 3.376** | Supported | 0.083 | 0.333 | 1.225 | 0.333 | - | 0.056 |

** p-value, <0.01, one-tailed, >1.960 of t-value
* p-value, <0.05, one-tailed, >1.645 of t-value
elements of linkages, maintenance, design and personal satisfaction have been influenced towards the cycling environment whereby it parallels with other studies' findings [22]–[24]. This is the complementation of evaluation for both macro and micro-scales. For instance, the high value of $R^2$ indicates that perception, preference and satisfaction have a significant to predict bike-built environment.

Lastly, the effective bikeway design factors can be revealed such as lighting provision, continues cycling network, shaded trees incorporated, greens spaces integration, sufficient width, proper surface and material selection are the key elements for the enhancing cycling participation among residents [27]. Although the $P$ value is weak it still has a positive effect on cycling participation. It also has supported the theoretical predictors when the people awoke (perceived environment) and the setting support provided (bike-built environment) would lead the high cycling participation (behaviour) [8], [9]. In conclusion, the impact of residential-bike built environment was confirmed with significant influenced on cycling participation among residents.

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APPENDIX

Appendix A

![Figure 2. The Measurement Model Result (Reliability And Validity Test).](image1)

![Figure 3. The Bootstrapping Structural Model Result (Hypothesis Testing).](image2)

| Constructs       | Code | Indicators                                                                                           |
|------------------|------|------------------------------------------------------------------------------------------------------|
| Perceived perception | PER4 | There are convenient cycling infrastructure provided in my residential neighbourhood                  |
|                  | PER5 | The street network system is continued with other infrastructure including bikeways.                 |
|                  | PER6 | The nearest public facilities like a bus stop, school and commercial area are difficult to reach by bicycle |
|                  | PER8 | The Malaysia climate does not prevent me from doing cycling activity within my residential neighbourhood |
|                  | PER9 | The natural setting in the residential neighbourhood is pleasant for cycling activity                 |
| Perceived preference | PRE1 | I prefer a variety of slopes and gradient of bikeways                                               |
|                  | PRE2 | I prefer smooth pavement types and evenness condition                                               |
|                  | PRE3 | I prefer a dedicated cycle path on each side of the road                                             |
|                  | PRE4 | I prefer security aspects such as speed limit, speed bump and signage                                |
|                  | PRE5 | I prefer direct bikeway system, proximate and easy to access.                                       |
|                  | PRE6 | I prefer scenic views such as natural elements and greenery                                         |
| Perceived satisfaction | SAT1 | I am comfortable cycling within unshaded bikeway during daytime in my residential neighbourhood        |
|                  | SAT2 | I am pleased the bikeway in my residential neighbourhood that links with the key destination such as parks, school and shops |
|                  | SAT3 | I enjoy the well-maintained and free from surface defects such as potholes, root damage and broken up the surface of bikeway |
|                  | SAT4 | I am satisfied with the bikeway design in term of sufficient width, the suitable material used and excellent facilities provided |
|                  | SAT5 | I am satisfied with the overall bikeway system that includes personal safety, convenience and enjoyment |
|                  | BDF2 | The bikeway in the residential neighbourhood needs to provide street lightings to                      |
| Bike built environment | BDF5 | The bikeway within the residential neighbourhood needs to be a well-connected and continuous network. |
|------------------------|------|--------------------------------------------------------------------------------------------------|
|                        | BDF7 | The bikeway in the residential neighbourhood should provide shaded trees and colourful shrubs along the bikeway. |
|                        | BDF9 | The bikeway in the residential neighbourhood could not be incorporated into open spaces, green space and parks |
|                        | BDF10| The minimum width and surface required for one-way of dedicated bikeway are 2 - 2.5 meter and asphalt concrete. |
|                        | BDF11| The sustainable material selection, easy to maintain and durable is the primary consideration for bikeway design |
| Participation         | PART6| I will spend about …………….. when I do cycling activity |
|                       | PART7| Travel distance that I prefer for cycling is between |
|                       | PART8| I will do cycling for about …………….. times |