Fuzzy Conjoint Modelling in Studying User Willingness to Switch to Bicycle as Transportation in Ipoh City

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Abstract. The increase of vehicles on the road contributed to the unsustainable city. The user dependence on motorised vehicles such as cars, motorcycles, vans, buses, and trucks should be reduced. Bicycle as transportation is the alternative methods that can be done as active transportation. The usage of bicycle can be reducing traffic, improve health, and reduce environmental pollution. As a model to assess the willingness of consumers to switch to bicycle transportation, total of 400 questionnaires were distributed in Ipoh city. The analysis uses fuzzy conjoint model as introduced by Zadeh and Tuksen to assess the extent to which consumers are willing to shift to cycling transport. The findings concluded, there are 6 strategies to improve the level of bicycle use special facilities for cyclists, a special crossing for cyclists, cycle parking provision, the application of the current cycle, associated facilities and bicycle users, and location of routes for cyclists.

1. Introduction

Latest town development and current climate change necessitate that we reconsider and analyse ongoing city development and management. Flash flood, landslide, thunderstorm, extreme greenhouse effect, global rising temperature and widespread air pollution are all impacts from significant climate change [1]. A sustainable city development in Malaysia revolves around 10 major criteria including culture & family, environmental administration, urban disaster, urban demography, ecological support, awareness & education, city services, natural resources management, city economics and public health. Motorised vehicles is the main contributing factor to an unsustainable environment besides manufacturing industry, development activities, power generation, land clearing and open air burning.

Ipoh is a city with a rich ecosystem and heritage that should be sustained. But now, city development is so rapid that the city sustainability is significantly affected. All main roads face serious congestion problem during peak hours. An effective way to reduce traffic congestion in big cities is the optimal use of bicycles. The use of bicycles as active transportation is popular in big cities around the world for instance in China, Belgium, Switzerland, Japan, Finland, Norway, Sweden, Germany, Denmark.
and Netherland. Moreover, in certain countries, the use of bicycles as a public transportation, or better known as bicycle sharing concept, has also been widely adopted. This concept doesn’t require high cost and it is suitable for short distance travels not more than five kilometers. Japan for example, despite being acknowledged as a major automotive manufacturer – with Honda and Toyota being the most well-known brands, still adopts the culture of bicycle as a mode of transportation. Abdullah O.K. Rahmat [2] stated that this system was introduced to reduce pollution.

![Figure 1. Ipoh city scenery](image)

2. Research Methodology

To analyse the level of priorities placed by respondents with respect to the use of bicycle as a mode of transportation, researchers adapted the fuzzy conjoint method introduced by Turksen [3]. Furthermore, Turksen and Willson [4] had also used the fuzzy conjoint method in a group model based on the priority model. Indeed, the fuzzy conjoint model is often used in the business sector to identify consumers’ preference level for a particular product. A study by Bass and Talarzyk [5] stated that preferences for a particular brand or product related to attitude based on beliefs in relative importance to each attribute. In another study, Dhar [6] said that user preference levels include subjective, fuzzy, doesn’t persist, unstable or consistent.

Based on this model, a set of fuzzy R was designed to represent the hierarchy of responses against each specific characteristic. In this approach, the levels for each selected attribute was defined. To determine respondents’ preference, the use of basic likert scale was identified as follows:

i. Strongly not preferred
ii. Not preferred
iii. Not sure
iv. Preferred
v. Strongly preferred

The fuzzy set theory was used to solve for formulation activities which are not precise, uncertain and fuzzy [7][8]. According to Baheri et al.[9] the fuzzy set theory is an extension of classic set theory and probability theory. Classic set theory only uses the values of 0 and 1, which is {0,1}, but fuzzy set theory uses the range of values between 0 and 1, which is (0,1). Fuzzy theory can be used to represent ambiguity or uncertainty that exist in the linguistic variables definition. Linguistic variables are represented by terms such as strongly not preferred, not preferred, not sure, preferred and strongly preferred. The figure below shows the concept of linguistic variables for beliefs.
The equation below is the fuzzy conjoint model adapted from Turksen (1992).

\[ \mu_R (y_j, A) = \frac{\sum_{i=1}^{T} Wi}{\sum_{k=1}^{K} Wk} \mu_{Bi} (x_j, A) \]

Where:

- \( W_i \) = Weightage that represent respondents' preference level / against all respondents in the study
- \( A \) = Criteria being considered
- \( \mu_{Bi} (x_j, A) \) = Degree of association for linguistic values B for respondent i towards item A based on linguistic values \( x_j = 1,2,3,\ldots,k \)
- \( K \) = The number of linguistic values used
- \( N \) = The number of respondents
- \( \mu_k (y_j, A) \) = Estimated degree of association for linguistic values R for all respondents towards item A based on linguistic values \( y_j = 1,2,3,\ldots,k \)

The table below shows the early definition for the linguistic values of the fuzzy set for variables preference level adapted from Yahaya and Mohamad [10]. This definition was based on Turksen and Willson [11].

| Linguistic variables | Linguistic values |
|----------------------|-------------------|
| Strongly not preferred | \{1/1, 0.75/2, 0.5/3, 0/4, 0/5\} |
| Not preferred | \{0.5/1, 1/2, 0.75/3, 0.25/4, 0/5\} |
| Not sure | \{0/1, 0.5/2, 1/3, 0.5/4, 0/5\} |
The formula used to determine the degree of similarity between two fuzzy sets as follows:

\[ S(F, M) = \frac{F \cdot M}{\max (F \cdot F, M \cdot M)} \]

Where

\[ F = \mu_F (x_1), \mu_F (x_2), \ldots \]
\[ M = \mu_M (x_1), \mu_M (x_2), \ldots \]

\( F \) and \( M \) are vector \( X = (x_1, x_2, \ldots) \), where \( \cdot \) means dot product.

Table 2. Preference items for bicycle transportation.

| NO. | ITEM                                                                 |
|-----|----------------------------------------------------------------------|
| 1   | Bicycle lanes distinctly separate from roads for motorised vehicles  |
| 2   | Bicycle lanes separated using blocks                                 |
| 3   | Bicycle lanes by the roadside                                       |
| 4   | Cyclists sharing the same roads with motorised vehicles             |
| 5   | Covered bicycle lanes                                               |
| 6   | Non-covered bicycle lanes                                           |
| 7   | Lanes on the left and right of roads lined with trees for shade      |
| 8   | Lanes lined with fragrant flower plants                             |
| 9   | The use of overhead bridge                                          |
| 10  | The use of traffic lights                                           |
| 11  | Absence of control                                                  |
| 12  | Involvement of authority such as the police                         |
| 13  | Covered bicycle parking                                             |
| 14  | Multi-storey bicycle parking                                        |
| 15  | Non-covered bicycle parking                                         |
| 16  | Combination of covered and non-covered                              |
| 17  | Bicycle parking near shops                                          |
| 18  | Separate parking for bicycles and cars by the roadside              |
| 19  | Automated bicycle parking                                           |
| 20  | Bicycle parking without security or locks                           |
| 21  | Complete cycling outfit including safety helmet and shoes           |
| 22  | Everyday wear                                                       |
| 23  | Office wear                                                         |
| 24  | Traditional wear (pelikat sarong)                                   |
| 25  | Rest and relaxation facilities (R&R)                                |
| 26  | Bicycle parking                                                     |
| 27  | Able to carry bicycle in public transportation                      |
| 28  | Separate lanes from motorised vehicles to avoid congestion          |
| 29  | Bicycle routes nearby workplace                                     |
| 30  | Bicycle routes nearby schools and higher education institutions      |
| 31  | Bicycle routes nearby shops and malls                               |
| 32  | Bicycle routes nearby recreational areas                            |
The following were the steps in fuzzy conjoint analysis after data collection process was conducted in Ipoh City. The first step was to determine the items that influence users’ preference when using bicycles based on incentives and disincentives as listed in Table 2.

The second step was to define the value measurement scale for the five fuzzy linguistic value as introduced by Turksen and Willson [12]. Linguistic variables involved are as follows, where \( L_k = \{\text{strongly not preferred, not preferred, not sure, preferred, strongly preferred}\} \).

\[
\begin{align*}
L_1 &= \begin{bmatrix}
0.0 & 0.25 & 0.5 & 0.75 & 1
\end{bmatrix} \\
L_2 &= \begin{bmatrix}
0.0 & 0.25 & 0.5 & 0.75 & 1
\end{bmatrix} \\
L_3 &= \begin{bmatrix}
0.0 & 0.25 & 0.5 & 0.75 & 1
\end{bmatrix} \\
L_4 &= \begin{bmatrix}
0.0 & 0.25 & 0.5 & 0.75 & 1
\end{bmatrix} \\
L_5 &= \begin{bmatrix}
0.0 & 0.25 & 0.5 & 0.75 & 1
\end{bmatrix}
\end{align*}
\]

Next, in the third step, questionnaires distributed to 400 respondents were analysed. Respondent sets were marked as \( R = (R_1, R_2, R_3, R_4, R_5, ..., R_{400}) \). Preference set for the 32 questions by the 400 respondents were tabulated as \( 1 = (4, 4, 5, ..., 5) \) as shown in Table 3 below.

**Table 3. Respondents’ opinion on preference items.**

| R1 | R2 | R3 | Rn | R400 | \( \sum \) |
|----|----|----|----|------|--------|
| 1  | 4  | 4  | 4  | .    | 5      | 1926   |
| 2  | 1  | 5  | 5  | .    | 4      | 1500   |
| 3  | 4  | 1  | 2  | .    | 2      | 789    |
| 4  | 2  | 2  | 1  | .    | 1      | 571    |
| 5  | 2  | 4  | 5  | .    | 5      | 1649   |
| n  | .  | .  | .  | .    | .      | .      |
| 32 | 2  | 2  | 4  | .    | 4      | 1395   |

The fourth step was to compute the weightage for the evaluation of each respondent against the evaluation of all 400 respondents by dividing the value for the individual respondent against the sum of values for total respondents (refer to Table 4).

**Table 4. Weightage scale for respondents’ choices.**

| W1   | W2   | W3   | Wn   | W400 |
|------|------|------|------|------|
| 1    | 4/1926 | 4/1500 | 4/789 | .    | 5/1395 |
| 2    | 1/1926 | 4/1500 | 5/789 | .    | 4/1395 |
| 3    | 4/1926 | 4/1500 | 2/789 | .    | 2/1395 |
| 4    | 2/1926 | 4/1500 | 1/789 | .    | 1/1395 |
| 5    | 2/1926 | 4/1500 | 5/789 | .    | 5/1395 |
| n    | .    | .    | .    | .    | .      |
| 32   | 2/1926 | 4/1500 | 4/789 | .    | 4/1395 |
The fifth step was to compute the degree of association of the linguistic value for the fuzzy set for each respondent. R value was derived by multiplying the weightage to linguistic value of the fuzzy set definition as the respondents’ value as shown in Table 5.

Table 5. Degree of association for all 400 respondents towards linguistic values.

|   | L1  | L2  | L3  | L4  | L5  |
|---|-----|-----|-----|-----|-----|
| R1| 0.0000 | 0.0005 | 0.0016 | 0.0021 | 0.0010 |
| R2| 0.0000 | 0.0005 | 0.0016 | 0.0021 | 0.0010 |
|  |  |  |  |  |  |
| R400| 0.0000 | 0.0000 | 0.0013 | 0.0019 | 0.0026 |

The sixth and final step was to compute the linguistic value of the fuzzy set for the 400 respondents, which is Lₜ by summing the degree of association for each domain set value separately.
Table 6. Summation of degree of association.

| QUESTION | L1    | L2    | L3    | L4    | L5    |
|---------|-------|-------|-------|-------|-------|
| 1       | 0.0010| 0.0350| 0.5343| 0.7835| 0.9304|
| 2       | 0.0507| 0.2765| 0.7020| 0.8775| 0.5453|
| 3       | 0.4563| 0.8048| 0.7117| 0.3685| 0.1204|
| 4       | 0.6375| 0.6756| 0.6173| 0.3091| 0.1278|
| 5       | 0.0400| 0.1402| 0.5879| 0.7433| 0.7841|
| 6       | 0.4446| 0.6059| 0.6851| 0.4418| 0.1851|
| 7       | 0.1300| 0.3494| 0.6652| 0.7309| 0.5397|
| 8       | 0.1754| 0.3566| 0.6561| 0.7055| 0.5125|
| 9       | 0.0092| 0.0696| 0.5558| 0.7921| 0.8792|
| 10      | 0.0326| 0.2200| 0.6720| 0.8740| 0.6234|
| 11      | 0.7622| 0.7226| 0.6006| 0.1555| 0.0366|
| 12      | 0.3522| 0.6872| 0.7038| 0.4704| 0.2402|
| 13      | 0.0027| 0.0690| 0.5662| 0.8109| 0.8650|
| 14      | 0.0691| 0.2378| 0.6500| 0.8121| 0.6310|
| 15      | 0.4050| 0.6525| 0.6969| 0.4799| 0.2013|
| 16      | 0.3824| 0.5897| 0.6813| 0.4895| 0.2550|
| 17      | 0.0644| 0.2102| 0.6249| 0.7615| 0.7350|
| 18      | 0.1524| 0.3900| 0.6649| 0.6792| 0.6656|
| 19      | 0.0581| 0.1715| 0.6047| 0.7820| 0.7636|
| 20      | 0.7083| 0.5312| 0.3541| 0.0000| 0.0000|
| 21      | 0.0175| 0.0748| 0.5411| 0.7574| 0.8938|
| 22      | 0.0376| 0.2437| 0.6853| 0.8769| 0.5860|
| 23      | 0.3447| 0.6789| 0.6981| 0.4673| 0.2426|
| 24      | 0.6169| 0.6814| 0.6068| 0.2822| 0.1593|
| 25      | 0.0460| 0.1219| 0.5618| 0.7518| 0.8303|
| 26      | 0.0365| 0.2199| 0.6715| 0.8528| 0.6206|
| 27      | 0.4734| 0.6488| 0.6625| 0.3915| 0.2017|
| 28      | 0.3051| 0.4955| 0.6435| 0.5368| 0.4078|
| 29      | 0.1446| 0.2508| 0.6032| 0.6912| 0.6490|
| 30      | 0.1311| 0.3424| 0.6513| 0.7101| 0.5663|
| 31      | 0.2634| 0.4273| 0.6424| 0.5846| 0.4519|
| 32      | 0.0953| 0.2043| 0.6054| 0.7484| 0.6939|
3. Results and Discussion

The first strategy proposed was customised facilities for cyclists in Ipoh City. For this section, eight questions were posed to respondents. Each respondent had given different responses. Two items had yielded the “strongly preferred” linguistic value result. The response recorded with weightage value of 0.9304 was for bicycle lanes to be separated from roads for motorised vehicles. Another item under “strongly preferred” was covered bicycle lanes with weightage value of 0.7841. Three items under the linguistic value “Preferred” were identified, which were bicycle lanes separated using blocks, lanes on the left and right of roads lined with trees for shade, and lanes lined with fragrant flower plants. The respective values for these items were 0.8775, 0.7309 and 0.7055. However, there were respondents who chose the linguistic value “Not sure” for the item non-covered bicycle lanes with weightage value of 0.6851. For the item bicycle lanes by the roadside, the linguistic value result was “Not preferred” with a weightage value of 0.8048. This was also the case for the item cyclists sharing the same roads with motorised vehicles, except with a lower weightage value of 0.6756.

The second strategy was providing dedicated crossing facilities for cyclists. Research finding only showed one item under the category “Strongly preferred” which was the use of overhead bridge. The weightage value was 0.8792. This was followed by the use of traffic lights with weightage value of 0.8740 under the category “Preferred”. However, for the question posed about the involvement of authority such as the traffic police and Road Transport Department, the result was “Not sure”. The weightage value for this item was 0.7038. For the item about crossing with the absence of control, the linguistic value found was “Strongly not preferred” with weightage of 0.7622.

The third strategy was providing bicycle parking. Researchers’ initial perception was that bicycle users do not require covered bicycle parking, similar to motorcycle users who park their motorbikes anywhere regardless whether the space is covered or otherwise. Evidently, this premature assumption was unfounded. Based on research finding, the linguistic value for the item covered bicycle parking was “Strongly preferred” with a weightage of 0.8650. Four items were found to be under the category “Preferred” which were multi-storey bicycle parking, bicycle parking near shops, separate parking for bicycles and cars by the roadside, as well as automated bicycle parking. The weightage values for these items were 0.8121, 0.7615, 0.6792 and 0.7820 respectively. Items with linguistic value “Not sure” were non-covered bicycle parking and combination of covered and non-covered parking with their weightage at 0.6969 and 0.6813 respectively. Finally, there was only one item with linguistic value “Strongly not preferred” which was bicycle parking without security or locks with a weightage value of 0.7083.

The fourth strategy involved cyclist outfit when cycling. It is acknowledged that safety aspect is very important when cycling on busy roads. Road users are constantly exposed to risks of accidents which can be fatal. The respondents had concurred by choosing the linguistic value “Strongly preferred” for the item complete cycling outfit including safety helmet and shoes. The weightage value recorded for this question was 0.8938.

For everyday wear or normal clothing, the weightage value was found to be 0.8769 which was in the “Preferred” category. As for office wear or working attire, the item fell under the category “Not sure” with a weightage value of 0.6981. For the final question under this section, respondents were also asked about traditional wear such as pelikat sarong. The result was “Strongly not preferred” with a weightage value of 0.6814.

The fifth strategy proposed was providing facilities for the convenience of cyclists. In general, not many facilities are built specifically for cyclists in majority of countries around the world, except for developed countries with an established policy to encourage the use of bicycles as daily mode of transportation. Analysis results showed that most respondents had chosen the item rest and relaxation facilities for cyclists as the most important factor with a weightage value of 0.8303. A dedicated rest area was expected to be a need in an area with hot weather all year round. So it was not surprising that most respondents saw this facility as a requirement in Ipoh.

As for the item bicycle parking, the weightage value found in this research was 0.8528 which was “Preferred”. Meanwhile, most respondents had selected “Not sure” for the ability to carry bicycles in
public transportation, as well as for the item separate lanes from motorised vehicles to avoid congestion. The weightage values for these two factors were 0.6625 and 0.6435 respectively.

The sixth strategy involved the location of routes for the cyclists. Each item yielded a different weightage value. However, the results showed that the linguistic value “Preferred” was most frequently selected. The weightage value for bicycle routes nearby workplace was 0.6912, for bicycle routes nearby schools and higher education institutions 0.7101, and for bicycle routes nearby recreational areas 0.7484, all under the category “Preferred”. On the other hand, there was one item with the linguistic value “Not sure” which was bicycle routes nearby shops and malls with a weightage value of 0.6424.

Evidently, the location of bicycle routes plays an important role to determine how likely the respondents in this research demography will switch to bicycle as a mode of transportation. Most respondents had given the “Preferred” linguistic value for bicycle routes nearby their workplace, regardless whether they were working in the civil service or in the private sector. Bicycle routes nearby schools and higher education institutions as well as recreational areas also proved to be of utmost importance.

![Figure 3: Covered and non-covered bicycle parking.](image)

### 4. Conclusion

Despite Japan’s capability to produce various types of cars filling up roads all over the world, its own society is content and takes pride in using bicycles; a mode of transportation that is not only cheaper and more convenient, but is also more environmentally friendly, devoid of pollution impact which could threaten global temperature stability [13].

This research had contributed a significant implication towards discovery of ideas and new findings in transportation system, especially in the area of non-motorised vehicles in Ipoh City specifically, and in Malaysia generally. The findings and results ought to be considered by local authorities such as the City Council, the Department of Town and Country Planning, and the Public Works Department to upgrade the infrastructure for bicycle transportation system. This includes dedicated lanes for cyclists to experience a safer journey compared to sharing roads with motorised vehicles such as cars and buses. This will affirm that each road user has the rights to fair use of road facilities.

At the federal government level, a dedicated budget to upgrade bicycle transportation system need to be allocated adequately so that the relevant authorities will have sufficient funding to improve
infrastructure in order to encourage the public to switch to bicycles as their means of transportation. In facing global challenges, there are no other unique ways to resolve them other than to increase user awareness, to be more concerned and conscientious towards their cities. According to Anable (2005), psychological factors such as perception, identity, social norms, and habits are increasingly being studied to understand travel behaviours.

Developed countries around the world such as Holland, Denmark, Finland, German, Sweden and Belgium had long adopted a policy which sides more towards non-motorised road users [14]. It is hoped that this change in stance can inspire and become a basis for Malaysians to switch to an established transportation system that supports a sustainable city.

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REFERENCES

[1] Rosilawati Zainol, R, Mohamad@Ahmad, I, Ahmad, F & Nordin NA 2014, Mesra pejalan kaki di bandar warisan, Penerbit Universiti Malaya, Kuala Lumpur.
[2] Abdullah O.K. Rahmat, RA 2015, Perancangan pengangkutan bandar, Penerbit Universiti Kebangsaan Malaysia, Bangi.
[3] Turkessen, IB 1992, ‘Fuzzy expert systems for IE/OR/MS’, Fuzzy Sets and System, vol. 51, no. 1, pp. 1–27.
[4] Turkessen, IB & Willson, IA 1994, ‘A fuzzy preference model for consumer choice, Fuzzy Sets and Systems, vol. 68, no. 3, pp. 253–266.
[5] Bass, FM & Talarzyk, WW 1972, ‘An attitude model for the study of brand preference’, Journal of Marketing Research, vol. 9, no. 1, pp. 93–96.
[6] Dhar, R 1995, ‘New directions in behavioral decision theory: implications for consumer choice,’ Advance in Consumer Research, vol. 22, pp. 203.
[7] Alriksson, S & Oberg, T 2008, ‘Conjoint analysis for environmental evaluation. A review of methods and applications’, Environmental Science Pollution Research, vol. 15, no. 3, pp. 244–257.
[8] Soutar, GN & Turner, JP 2002, ‘Students’ preferences for university: A conjoint analysis,’ International Journal of Educational Management, vol. 16, no. 1, pp. 40-45.
[9] Baheri E, Dalvand MR, Ansarinejad A, Mirm-Narges S, & Hatami-Shirkouhi L 2011, ‘A fuzzy conjoint analysis approach for evaluating credit card services: A case study of Iranian bank,’ African Journal of Business Management, vol. 5, no. 7, pp. 2753–2765.
[10] Yahaya, YH & Mohamad, N 2011, ‘Designing software usability measurement using fuzzy set conjoint model’, in International Conference on Computer Communication and Management, Australia, 2-4th May 2011, Sydney, Australia.
[11] Turkessen, IB & Willson, IA 1995, ‘A fuzzy set model for market share and preference prediction, European Journal of Operational Research, vol. 82, no. 6, pp. 39–52.
[12] Turkessen, IB & Willson, IA 1995, ‘A fuzzy set model for market share and preference prediction, European Journal of Operational Research, vol. 82, no. 6, pp. 39–52.
[13] Mat Yazid, MR, Jamaludin, SA, Tuan Yaakub, NMI & Borhan, MN 2015, ‘Pendekatan Pemodelan Konjoin Kabur dalam Pengangkutan Aktif,’ Advanced Journal of Technical and Vocational Education, vol. 1, no. 2, pp. 160–168.