Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 00 (2018) 000–000

Transportation Research Procedia

www.elsevier.com/locate/procedia

World Conference on Transport Research - WCTR 2019 Mumbai 26-31 May 2019

Analysis of user perception towards a key set of attributes related to Bicycle-Metro integration: A case study of Hyderabad, India

Jay Panchal[a], Bandhan Bandhu Majumdar[a,]*, V.Vinayaka Ram[a], and Debasis Basu[b]

Department of Civil Engineering, BITS Pilani Hyderabad Campus, Telangana-500078
School of Infrastructure, IIT Bhubaneswar, Argul, Jatni Odisha-752050

Abstract

Presently, there is no consensus on the factors which might influence a metro-commuter towards choosing the bicycling as a last mile connectivity option in Indian context. Hence, a broader understanding of the end-user preferences towards key set of determinants related to bicycle-metro sharing is necessary to formulate effective policy measures, which would subsequently lead to sustainable cities and improved well-being of commuters. This article is an attempt to demonstrate a scientific approach to prioritize among an important set of determinants influencing commuter's decision to use bicycle as an access or egress mode to metro rail. The demonstrated methodology also makes an effort to understand the sources of heterogeneity towards user perception as well. Hyderabad, an Indian metropolitan city, which has recently introduced metro-rail, has been selected as the case study city. Initially, a set of key determinants related to bicycling in general and bicycle-metro integration in particular is identified and commuter's perception towards these determinants is collected based on a typical five-point likert scale item. Subsequently, the sources of heterogeneity among user responses were explored by using Kruskal Wallis H test, a non-parametric statistical measure. Results clearly indicate that user perception towards several determinants were significantly influenced by trip-specific characteristics such as trip frequency, trip purpose etc. Overall, a clear evidence of heterogeneity among user perceptions on the factors indicates the need for conducting separate analyses for different socio-economic sub-groups. Prioritization of the identified determinants was carried out by an established MADM technique, namely, RIDIT-analysis for different categories of commuters.

Peer-review under responsibility of WORLD CONFERENCE ON TRANSPORT RESEARCH SOCIETY.

Keywords: Bicycle-metro integration; User-perception; Multi-Attribute Decision Making; RIDIT; Heterogeneity; Kruskal-Wallis H-Test

1. Background

The exponential growth of Indian urban population has resulted in increased demand for efficient public transport services for carrying large number of passengers through congested urban areas. Ever increasing travel demand, especially in large cities, has far exceeded the limited supply of transport infrastructure and services available in Indian cities. As of now, almost 90% of PT users travel by buses and rely on a combination of buses, minivans, auto rickshaws, cycle rickshaws and taxis. The current practice of running majority of the buses during the peak hours has forced majority of the commuters to take to alternative private and Para transit systems. With no exclusive right of way to the buses, as seen in majority of Indian urban cities, the buses are forced to travel along with all other vehicles,

Peer-review under responsibility of WORLD CONFERENCE ON TRANSPORT RESEARCH SOCIETY

including motorized and non-motorized private vehicles, Para transit systems, animal drawn vehicles and pedestrians, sharing the same road space. Due to the heterogeneity in the movement patters, sizes and shapes of different vehicles, the buses are forced to travel at very slow pace. Pucher et al. (2004) have observed that the buses are forced to travel at speeds as low as 10 km per hour during the peak hours in typical Indian cities. In addition to these issues, the problem of overcrowding of the buses is literally forcing the travelling public move away from bus transportation system, though it offers itself as the cheapest public transportation system. Metro rail system with exclusive structures, fixed guided systems, higher passenger capacity, lower air pollution and improved safety for passengers is rapidly replacing the bus system as the most popular public transportation system. Promotion of metro rail system with well-planned infrastructure coupled with effective feeder system could certainly result in a significant modal shift from motorized vehicles to metro rail.

While metro rail has become the solution for mass rapid transit in most Indian metros, transfer to and from stations, popularly known as the "first and last mile" connectivity remained a major concern to be dealt with. It is imminent that the success or failure of metro rail significantly depends on the efficiency of the access or egress mode planning. Currently available feeder systems include auto-rickshaws, taxis and share-cabs. However, all the feeder modes, being expensive, make the complete trip from the origin to the destination, costlier than the private mode of transportation. In addition, the emissions resulting from the motorized modes are causing the deterioration of the ambient air quality. Bicycle, a short-distance means of transport, offers advantages in the form of emission free, environment-friendly, economic, convenient and healthy alternative for accessing metro rail in India. However, unsafe and inadequate bicycling infrastructure in and around metro stations has restricted the use of both bicycle and metro together as a single trip. Hence, an investigation of the user perception towards bicycle-metro integration becomes instrumental to identify the areas of intervention.

A critical review clearly indicates that the bicycle and metro rail integration has been a relatively less explored area of research with significant promise. In India with the heterogeneous traffic mix, bicycle – metro integration is highly challenging and may need deeper understanding for its successful implementation. Till date, only a few researchers have attempted analyzing the scenario of using bicycle as a feeder system to metro. Further, not many evidences in the literature are found to have dealt with the attitudes towards cycling and metro as a combined-mode choice. While identification of factors is crucial for evaluation, it is also important that researchers test for heterogeneity across different groups for any specific factor. Such heterogeneity investigation across user groups will provide planners with a clear idea on difference in requirements across various user groups towards factors specific to metro rail-bicycle integration. In order to address these very important issues, this current study is taken up to demonstrate a scientific approach for analysis of user perception towards factors specific to metro rail-bicycle integration, where user perception towards a set of attributes is collected, analyzed and heterogeneity across user groups is investigated. Summary of the literature review, which was carried out during the current research is summarized and presented in the following section for ready reference.

2. Literature Review

This section is intended to provide a detailed background on existing literature on the research topic. For better understanding, this section is further sub-divided into the following sub-components, namely, a) review on factors influencing bicycle-metro integration, b) review of statistical techniques adopted for ranking of factors and c) review on investigation of heterogeneity across user responses.

2.1. Review on factors influencing bicycle-metro integration

This section attempts to provide a brief review of existing research literature available related to bicycle and metro integration. For a more focused discussion, a review of past attempts made to integrate bicycles and public transit systems is presented in a chronological manner. Among existing researches, Rietveld (2000) opined that bicycle can be an attractive access mode for the railways as saves waiting time for the users at bus or tram stops. He found that at the home end of the trip, bicycle seems to play a significant role with a share of 35% as an access mode, whereas the share is much lower at the activity end. He also found that potential bicycle users may be discouraged to cycle to metro due to the insufficient parking facilities for bicycles and associated high risk of bicycle theft at railway stations.

Parkin et al. (2008) reported that the individual and socio-economic characteristics such as gender, car ownership, age, proportion of students within the population, ethnicity, socio-economic class and income plays very important role towards one's choice to bicycle. In addition, a few other factors viz. physical determinants like journey distance, degree of urban density, terrain conditions (hilly / mountainous etc.) and weather related attributes such as mean temperature and rainfall have been observed to be influencing the bicycle mode choice in a significant manner.

In another study, Pucher and Buhler (2009) have mentioned about implementation of five main measures for promoting bicycle-transit integration as listed: a) Provision of bicycle parking at both rail stations and bus stops with shelter and adequate security; b) Multi-functional bike stations providing parking, bike rentals, repairs, parts and accessories, bike washing, showers and lockers and touring advice; c) Bicycle racks on buses, usually exterior, but occasionally interior storage; d) Bicycles on board vehicles, usually rail vehicles, sometimes with special bike racks, hooks or even bike cars on trains; e) Bike paths, lanes, and on-street routes leading to public transport stations and stops, thus facilitating the bike's role as feeders and collectors for public transport. They have also highlighted that although bicycling and public transport have considerable synergies, there are some inevitable conflicts such as inadequate parking at stations, concerns about safety and security of bicyclists etc. which needs to be considered carefully to increase the bicycle ride share as feeder to metros .

In their study, Bachand Marleau et al. (2011) have analyzed the travel behavior and preferences related to cycle–transit (C-T) integration. An attempt to explore the potential of integrating the transit with Montreal's public bicycle sharing system, Bixi (bicycle taxi) was made during this study. Three potential C-T user groups were identified through a factor–cluster analysis and it was observed that bringing a bicycle on transit was the preferred form of integration. Two alternatives of either facilitating bicycle parking at transit station or enabling the process of bringing bicycles on board transit were suggested during the same study. About 63% of the interviewed riders responded people positively to use bicycle as a feeder mode for metro rail. The other 37% of the riders chose not to go for bicycle feeder alternative due to the fact that the distance is too much for them to travel by bicycle. In addition, they were worried about the safety of their bicycles, being parked at the metro stations. It was also observed that the trip purpose is a critical factor determining user's choice decisions.

In another relevant study, Heinen and Bohte (2014) explored the extent to which attitudes relate to combined public transport–bicycle use for a single trip. It was inferred that journey distance plays a major role towards such integration or combined journey. The authors have observed that the users with more positive attitude towards both bicycle and public transport are more likely to become bicycle-transit commuters. In a recent study carried out by Zhao and Li (2017), the determinants of cycling as a transfer mode in metro station areas in Beijing were identified. Based on a multilevel logistic model, it was concluded that the travel distance is the most critical factor towards choosing bicycle as a transfer mode between metro stations and home or workplace. Personal factors such as age, income also play the major role on user's choice decision, it was observed. During the same study, other factors like the built environment of railway station areas, bicycle parking sites were observed to be influencing the bicycle-railway integration.

From the studies reviewed, factors relevant to the Indian conditions were chosen during the current research. Further, a detailed review on the works, involving prioritization of user perception based factors, was carried out and the summary is being presented in the following sections for ready reference.

2.2. Review of literature on prioritization of factors based on user perception

It is a well-known fact that a simple user ranking based on the mean score itself can be used as a tool for prioritization of factors. However, mean score fails to effectively represent the Likert type data. It is in this direction that an appropriate Multi attribute decision making (MADM) technique, capable of handling such data, is being used in almost all the studies involving the Likert type data.

RIDIT analysis is one MADM method which is very popular in handling and analyzing the ordinal data. RIDIT analysis is initially suggested by Bross (1958) and is used for comparing two or more ordered qualitative data sets. Between the two datasets, one is designated as a reference or base dataset and the other is compared with the reference dataset. The word-RIDIT is an abbreviated form of "Relative to an Identified Distribution and the suffix -it represents a transformation" (Sadhukhan et al. 2014). RIDIT analysis has been extensively used by many researchers for priority rankings. For example, Chang and Chang (2005) investigated recreational bicyclists' environmental preferences using RIDIT analysis and found safety to be the top-most factor influencing bicycle choice decisions. Among other studies, Bikash et al. (2010) used RIDIT analysis to explore the relative importance of factors associated with the choice of Nano car in India. RIDIT has also been used in health and clinical studies. Other techniques such as TOPSIS (Sadhukhan et al. 2014), AHP (Majumdar and Mitra, 2015) or Fuzzy-TOPSIS have also been previously deployed by researchers. However among all the available techniques, RIDIT has been observed to be more appropriate for analysis of Likert type data and hence been selected for this study.

2.3. Review on literature on investigation of heterogeneity across user responses

Checking the heterogeneity for the identified factors controlling the rider choice to choose bicycle as the last mile connectivity option for metro rail both within as well as across the cities, is crucial for the success of metro – bicycle integration attempts. In the context of bicycle-metro integration, this aspect has not been found to be reported in the literature. Vargha and Delaney (1998); Goh et al. (2014) have recommended use of non-parametric test such as Kruskal-Wallis H-test when the user perception is collected in ordinal scale. Lopez-zetina et al. (2006) have tried this technique to examine associations among Vehicle Miles Travelled (VMT), commute time, obesity and physical inactivity. Shiftan et al. (2003) used this technique to compare expert (consultants, academics and decision makers) perception towards different transport planning related policies. With the above reported examples, Kruskal-Wallis H-Test is being used in this study to check the differences among user perception towards various attributes influencing bicycle-metro integration.

Based on the detailed literature review, a clear understanding of the research context is developed and appropriate research gaps are identified. In this regard, this paper aims at addressing the following research gaps. Firstly, there is a significant lack of research efforts towards investigating user perception towards bicycle-metro integration, which could be a successful mode of transport in typical Indian context. Secondly, there is a lack of scientific efforts aimed at identification and prioritization of key attributes related to bicycle-metro integration using advanced statistical techniques. Thirdly, a lack of studies have been observed investigating heterogeneity across user perception. Fourthly and most importantly, majority of the existing researches are in the context of developed countries, whose user-characteristics as well as transportation characteristics is distinctly different than users belonging to developing countries such as India. Hence, there is a need to demonstrate a methodological framework to analyze user response towards factors influencing bicycle-metro integration relevant to typical Indian context. The following section presents a brief methodology for analysis of user perception towards a set of factors influencing bicycle-metro integration in Indian context.

3. Methodology

In this section, a step-wise methodological approach is presented for identifying a subset of distinct and independent attributes influencing bicycle-metro integration, where only a few important factors should be ranked based on appropriate MADM techniques.

Step-1: Identification of attributes relevant to Bicycle-metro integration in India: A brief review of existing research literature is undertaken to identify a key set of determinants influencing bicycling decision by metro users.

Step-2: Questionnaire Design and Data Collection: For collection of user perception towards the identified set of determinants, a survey questionnaire is designed in a typical Likert type scale and subsequently, data is collected from users to understand user perspective towards the bicycle-transit integration.

Step 3- Check for heterogeneity among user responses: Kruskal-Wallis H-test is used to check if user's perception towards a specific attribute differs across various population sub-groups.

Kruskal-Wallis H-test

Kruskal-Wallis H-test is a statistical test used to compare two or more than two independent groups with non-parametric datasets. Where, null hypothesis (H0): Median score against any variable is same across a specific population sub-group. Alternative hypothesis (H1): Median score against any variable is not same across a specific population sub-group.

For Kruskal-Wallis H-test, the test statistic H can be defined as the following:

$$H = \frac{12}{n(n+1)} \Sigma \frac{R_j^2}{n_j} - 3(n+1) \qquad (1)$$

Where, R_j= Rank sum for sample j, n= total number of sample, n_j= number of respondents in sample j (Betty and Toothaker, 1974)

To interpret the outcome of this test, p-values are checked for all groups.

Step-4: Ranking of factors using RIDIT Analysis: RIDIT analysis is used to rank the attributes for different user groups with respect to different socio-economic characteristics.

RIDIT is an established multi attribute decision making (MADM) approach proposed by Bross (1958). The name "RIDIT" was chosen for its analogy with "probits" and "logits". The first three letters of RIDIT mean ―Relative to an Identified Distribution‖. The last two letters "it" represent a type of transformation. Ridits are generally based on the observed distribution of a response variable for a specified set of individuals. This approach is very closely related to distribution-free methods based on ranks such as Wilcoxon Test (Bross, 1958). RIDIT possesses two very important properties. Firstly, it assigns a rank value to each class proportional to the relative frequency of observations in that class. Secondly, the rank value is standardized within 0 to 1. The latter property eliminates the problem of variation in the relative positions with respect to number of ranks. RIDIT technique appears to suppress the differences in distributional shape (Selvin, 1977).

Procedure

- Step-1: A reference dataset should be identified. For a typical Likert scale survey data, the total response can be considered as a reference dataset, if the population cannot be identified.
- Step-2: The frequency f_i for each category of responses, where j =1, ..., n should be calculated.
- Step-3: The mid-point accumulated frequency F_j for each category of responses needs to be estimated.

$$F_1 = \frac{1}{2} f_1$$

$$F_j = \frac{1}{2} f_j + \sum_{k=1}^{j-1} f_k \qquad \text{where k = 2, 3, 4, ….., n}$$

- Step-4: Compute RIDIT value Rj for each category of responses in the reference dataset.

$$R_j = \frac{F_j}{N} \qquad \text{Where, j=1, 2, 3, 4,……, n}$$

In the above expression, N is the total number of responses from the Likert scale survey. By definition, the expected value of R for the reference data set is always 0.5.

- Step-5: RIDITs and mean RIDITs for comparison datasets should be calculated. A comparison data set is comprised of the frequencies of responses for each category of a Likert-type scale item. If there are m Likert-type scale items in the response scale, there will be a total of m comparison data sets. RIDIT value r_{ij} should be calculated for every category based on the following form:

$$r_{ij} = \frac{R_j x \pi_{ij}}{\pi_i} \qquad \text{where i = 1, 2, 3, 4, …… , m}$$

π_{ij} is the frequency of category j for the ith scale item, and πi is a short form for the summation of frequencies for scale item i across all categories, i.e.

$$\pi_i = \sum_{k=1}^{n} \pi_{ik}$$

The mean RIDIT ρi for each Likert scale item should be calculated with the following expression

$$\rho_i = \sum_{k=1}^{n} r_{ik}$$

- Step 6: Compute confidence interval for ρi. When the size of the reference data set is very large relative to that of any comparison data set, the 95% confidence interval of any ρi is:

$$\rho i \pm \frac{1}{\sqrt{3\pi_i}}$$

- Step 7: Test the following hypothesis using the Kruskal-Wallis statistic W.

$$H_0 = \forall i, \rho i = 0.5$$

$$H_a = \exists i, \rho i \neq 0.5$$

$$W = 12 \sum_{i=1}^{m} \pi_i (\rho i - 0.5)^2$$

The general rules for interpreting the values of ρ are mentioned in the following section.

- Firstly, a scale item with its ρi value statistically deviating from 0.5 implies a significant difference in the response patterns between the reference data set and the comparison data set for the particular scale item. If the confidence interval of a ρi contains 0.5, then it is accepted that the ρi value is not significantly different from 0.5.
- Secondly, a low value of ρi is ranked higher over a high value of ρi because a low value of ρi indicates a low probability of being in a negative propensity.
- Thirdly, the response patterns of scale items with overlapped confidence intervals of ρ are considered, among the respondents, to be statistically indifferent from each other.

Based on the derived prioritization results derived from RIDIT analysis, necessary interpretations are conducted, which would be useful for bicycle-metro integration in Indian context. In this context, this research reports a pilot study with respect to Hyderabad, a metropolitan Indian city, where metro-rail has been in nascent stage. Positive perception of users towards various attributes could be useful for subsequent promotion of bicycle integration with public transit in Indian setting.

4. Identification of attributes relevant to Bicycle-metro integration in India

Based on a detailed review of existing research literature on various international literature related to bicycling in general and bicycle-transit integration in specific, a number of attributes relevant to Indian condition could be identified and can be further grouped a number of categories (Table-1)

Table-1: List of identified attributes relevant to Bicycle-metro integration in Indian context

Sl.	Factor Category	Attribute
1	Physical Attributes	Weather Condition
2		Terrain Condition
3	Journey related attributes	Access Time
4		Access Distance
5		Journey Comfort
6	Route Characteristics	Traffic Congestion
7		Risk from motorized vehicles
8	Bicycle Infrastructure related attributes	Bicycle Lane
9		Bicycle security
10		Bicycle parking facility
11		Bicycle Maintenance
12		Bicycle Rental Charge
13		Bicycle Rental Deposit

Subsequently, a Likert-type travel behavior survey is designed to elicit user perception against each attribute related to bicycling in general and bicycle-metro integration in particular.

5. Questionnaire Design and Data Collection

In this study, a travel behavior questionnaire was designed to elicit user's socioeconomic characteristics, trip making characteristics as well as individual perception towards bicycle metro integration attributes. The perception information was collected on a standard five-point Likert scale. Against each of the identified attribute (Table 1), users were provided with five different choices. The respondents were asked to provide their perceived level of importance against each of them in either of the five scales, namely, very high importance, moderate importance, neutral, low importance, very low importance. As part of an initial study, a total of 100 users were surveyed, out of which 18 responses were removed due to incomplete data and the remaining 82 complete datasets was considered for database development and subsequent analysis. One of the major limitations of this study is relatively lower sample size, however this study is considered to be a pilot study, results of which would be used as a basis for a detailed long-term study evaluating the bicycle-metro integration feasibility in Indian context. Table-2 presents the socio-demographic profile of the respondents in consideration.

Table-2: Sample statistics

Classification	Groups	Sample proportion
Gender	Male	77%
	Female	23%
Monthly Family Income (INR)	Up to 30000	27%
	30000 – 60000	43%
	More than 60000	30%
Trip purpose	Commuting	46%
	Non-commuting	54%
Trip Frequency	Frequent or regular (at least 3 times a week)	56%
	Irregular	44%

Subsequently, a preliminary analysis of the collected data is conducted for a basic understanding of user perception towards various attributes related to bicycling in general, bicycle-transit integration in particular across different socio-economic sub-groups (Table 3).

Table-3: Preliminary analysis of collected responses

Attribute	High Importance	Moderate Importance	Neutral	Low Importance
Weather Condition	50%	21%	10%	15%
Terrain Condition	16%	32%	24%	20%
Access Time	28%	29%	20%	21%
Access Distance	27%	32%	20%	20%
Journey Comfort	22%	30%	23%	20%
Traffic Congestion	22%	44%	16%	15%
Risk from motorized vehicles	28%	30%	18%	22%
Bicycle Lane	23%	35%	16%	21%
Bicycle security	30%	34%	13%	20%
Bicycle parking facility	24%	34%	23%	13%
Bicycle Maintenance	24%	33%	20%	22%
Bicycle Rental Charge	20%	30%	24%	21%
Bicycle Rental Deposit	22%	30%	21%	21%

Based on the preliminary analysis, it can be observed that factors such as weather condition has been perceived with high importance, moderate importance by 50% and 21% users respectively. This result clearly indicates that users perceive weather condition as a highly important attribute influencing bicycling decisions. In general, hot and humid weather condition in India is one of the major barriers towards successful integration of bicycle and public transit modes. Among route related characteristics, traffic congestion has also been perceived with high importance by 22% and moderate importance by 44% users. Risk from motorized vehicles or traffic safety has also been perceived as an important determinant by respondents. Such findings indicate that presence of heterogeneous traffic and associated externalities play a major role towards users not bicycling. However, factors such as terrain condition or journey comfort have been perceived with lower importance than other attributes, indicating their relatively less significant effect on user perception. Similarly, effect on other attributes could be inferred based on relative user perception against them. Subsequently, Kruskal-Wallis H-test is used to check the evidence of heterogeneity on user response towards the identified set of attributes.

6. Check for heterogeneity among user responses

Kruskal–Wallis test statistic is used to check heterogeneity in user response with respect to the identified attributes across different population subgroups for Hyderabad, India. The asymptotic significance or p-value derived for each statistic is reported in Table 4. If there is evidence of heterogeneity among user responses for a factor across a specific population subgroup, the respective p-value is less than .05. For example, the p-value reported against the factor, Bicycle lane, with respect to trip purpose 0.011) reveals the presence of heterogeneity i.e. both commuting and non-commuting users perceives the attribute bicycle lane significantly differently. On the other hand, an asymptotic p-value of 0.168 for weather with respect to gender indicates that both male and female perceive weather statistically similarly. For further insights on difference in user perception, the test is carried out across all user groups and the results in terms of asymptotic p-values are reported in Table 4.

Table 4: Summarized list of p-Values for Kruskal-Wallis H-test across different socio-economic classification

Attribute	Gender	Income	Trip Purpose	Trip Frequency
Weather Condition	0.168	0.02	0.205	0.00
Terrain Condition	0.158	0.025	0.305	0.00
Access Time	0.352	0.001	0.417	0.00
Access Distance	0.169	0.105	0.030	0.127
Journey Comfort	0.061	0.033	0.041	0.006
Traffic Congestion	0.120	0.279	0.010	0.00
Risk from motorized vehicles	0.241	0.026	0.373	0.070
Bicycle Lane	0.297	0.004	0.011	0.05
Bicycle security	0.292	0.244	0.691	0.004
Bicycle parking facility	0.106	0.094	0.076	0.048
Bicycle Maintenance	0.350	0.005	0.080	0.00
Bicycle Rental Charge	0.544	0.025	0.012	0.001
Bicycle Rental Deposit	0.812	0.061	0.077	0.036
All shaded cells indicate evidence of heterogeneity (95% confidence interval) or the difference in user perception is significant at 95% confidence interval				

Examining Heterogeneity with respect to Gender

Investigation of heterogeneity across male and female user groups with respect to different attributes clearly indicate that statistical difference among male and female respondents at 95% confidence interval for different attributes. However, at 90% confidence interval, male and female users were observed to have statistically significant difference towards the attribute "journey comfort". In general, a consistency in user perception could be observed between male and female respondents.

Examining Heterogeneity with respect to Monthly Family Income

Examination of evidence of heterogeneity with respect to different attributes clearly indicate significant statistical difference towards factors such as weather condition, terrain condition, access time, motorized vehicular risk, bicycle maintenance, bicycle lane, bicycle rental charge etc. This finding clearly indicates that monthly family income plays a major role on user perception towards choice decisions. Factors such as bicycle rental deposit and parking facility were observed to be statistically differently perceived by different user groups at 90% confidence interval.

Examining Heterogeneity with respect to Trip purpose

Exploring the evidence of heterogeneity towards the set of identified attributes influencing bicycle-metro integration with respect to trip purpose clearly indicates statistically significant difference between commuter and non-commuter users towards factors such as access distance, journey comfort, bicycle lane and bicycle rental charge etc. Trip makers including commuting and non-commuting trip makers were observed to perceive weather condition and terrain condition statistically similarly at 95% confidence interval.

Examining Heterogeneity with respect to Trip Frequency

Trip frequency seems to be a significant trip-related characteristics influencing user perception towards various attributes in consideration at 95% confidence interval. It clearly indicates that frequent and non-frequent trip makers would perceive different attributes in a statistically different manner, thus requiring further investigations in this respect.

The following section presents the ranking of the attributes by RIDIT, an extensively adopted MADM technique across different user groups with respect to the gender, income, trip purpose and trip frequency.

7. Ranking of factors using RIDIT Analysis and interpretation

In this section, the ranking or prioritization of identified factors are conducted based on RIDIT analysis technique. The theoretical basis is already presented in the methodology section. In this study, the ranking is derived across different user groups and further interpreted. For limited scope and space of this paper, a detailed description of RIDIT analysis is only presented for frequent trip-makers. Table 5 presents the summarized RIDIT analysis results for frequent trip makers in Hyderabad.

A significantly greater Kruskal-Wallis (W) value of 30.38 as compared to the critical chi-squared value with 12 degrees of freedom at 0.05 significance level [21.02] indicates that user responses on the importance of deterrents are statistically significantly different. Among the attributes, weather condition (ρ_i=0.68) is perceived as the top-most factor. This indicates that extreme hot and humid weather in India is a major concern for bicycling. Bicycle security (ρ_i=0.55), traffic congestion (ρ_i=0.54) and bicycle maintenance (ρ_i=0.53) are ranked as the second, third and fourth most important factors respectively. Access time (ρ_i=0.51) and risk from motorized vehicles (ρ_i=0.48) are ranked fifth and sixth respectively. Factors such as access distance (ρ_i=0.47) and bicycle parking facility (ρ_i=0.46) are ranked seventh and eighth respectively. Journey comfort (ρ_i=0.461) and Bicycle rental charge (ρ_i=0.458) are perceived as ninth and tenth attributes respectively. Bicycle Lane (ρ_i=0.37), Bicycle Rental Deposit (ρ_i=0.36) and Terrain condition (ρ_i=0.35) were perceived as least important attributes by users. Further, the rankings of different attributes are conducted across different user sub-groups. Rankings across other socio-economic sub-groups are summarized in Table 6 and interpreted in the following section.

Comparison of attributes rankings across user sub-groups

The rankings of the attributes are conducted through RIDIT analysis and the summarized results are presented in Table 6. Based on the results, weather condition has been perceived as the most important attribute across most of the user groups, whereas access distance has been perceived as the most important attribute by users with commuting trips. Among other attributes, traffic congestion has been perceived second by male and non-frequent users, whereas it is perceived with relatively less importance by frequent trip makers and users with monthly family income more than 60000 INR. Comparison of attribute rankings across male and female user groups reveal similar direction of prioritization except a number of attributes. For example, journey comfort has been perceived as the sixth most important attribute towards deciding whether to bicycle to metro or not by male users and twelfth by female users. This could be attributed to the fact that male users being more frequent than female users perceive comfort as an important one. Similarly, risk from other motorized vehicles or a measure of road safety has been perceived as more important determinant by male users than their female counterparts. This finding clearly indicates that unsafe bicycling environment is a major barrier towards successful bicycle metro integration in India. Similarly income was also observed to play an important towards user perception. Significant difference in factor prioritization could be observed among respondents with different monthly family income. Presence of an exclusive bicycle lane has been perceived as the most important attribute by the users with high income, whereas users with relatively less income perceived bicycle lane rather less important. This result clearly indicates that provision of an exclusive bicycle lane may significantly attract the high income or choice users to use bicycle as an access or egress mode to metro rail in typical Indian context. Difference in user ranking is also observed with respect to trip purpose and trip frequency. A very interesting observation could be made that bicycle rental charge has been perceived as very low by almost all user groups, indicating that even high rental charge would not be a major barrier.

Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 00 (2018) 000–000

Transportation Research Procedia

www.elsevier.com/locate/procedia

Table-5: RIDIT-Based prioritization

RIDIT Values for reference data set						**RIDIT values for comparison data set**								
Attributes	**Very high**	**High**	**Neutral**	**Low**	**Very low**	**Very high**	**High**	**Neutral**	**Low**	**Very low**	ρ_i	**LB**	**UB**	**Rank**
Weather Condition	0	3	3	9	31	0	0.0047	0.043	0.228	0.183	0.68	0.60	0.77	1
Terrain Condition	1	3	15	17	10	0	0.0038	0.06	0.141	0.274	0.43	0.35	0.52	13
Access Time	1	2	9	17	17	7.27E-05	0.0019	0.038	0.184	0.311	0.51	0.45	0.62	5
Access Distance	1	3	13	16	13	7.27E-05	0.0028	0.051	0.206	0.201	0.47	0.38	0.55	7
Journey Comfort	1	3	12	19	11	7.27E-05	0.0028	0.055	0.173	0.238	0.461	0.38	0.55	9
Traffic Congestion	0	1	8	23	14	0	0.0037	0.06	0.162	0.238	0.54	0.46	0.63	3
Risk from motorized-veh	0	4	14	13	15	7.27E-05	0.0028	0.064	0.184	0.183	0.48	0.39	0.56	6
Bicycle Lane	0	5	10	21	10	0	0.0047	0.051	0.184	0.219	0.46	0.37	0.54	11
Bicycle security	0	4	6	19	17	0	0.0057	0.051	0.194	0.183	0.55	0.46	0.63	2
Bicycle parking facility	0	4	14	15	13	0	0.0009	0.047	0.194	0.293	0.46	0.38	0.55	8
Bicycle Maintenance	0	1	11	18	16	0	0.0038	0.026	0.205	0.311	0.53	0.45	0.62	4
Bicycle Rental Charge	0	5	12	17	12	0	0.0009	0.034	0.249	0.256	0.458	0.37	0.54	10
Bicycle Rental Deposit	0	6	12	18	10	0	0.0028	0.012	0.097	0.567	0.43	0.36	0.52	12
fj	4	44	139	222	189									
I/2 * fj	2	22	69.5	111	94.5									
Fj	2	26	117.5	298	503.5									
Rj	0.003	0.04	0.193	0.53	0.84									

Peer-review under responsibility of WORLD CONFERENCE ON TRANSPORT RESEARCH SOCIETY

Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 00 (2018) 000–000

Transportation Research Procedia

www.elsevier.com/locate/procedia

Table 6: Ranking of factors across user groups

Attribute	Male	Female	Inc. less than 30000 INR/M	Inc. 30000-60000 per.month	Inc. more than 60000 INR/M	Trip makers making commuting trips	Trip makers making non-commuting trips	Frequent trip-makers	Non-Frequent trip-makers
Weather Condition	1	1	1	1	2	3	1	1	1
Terrain Condition	11	13	13	13	11	13	13	12	13
Access Time	8	5	9	2	9	8	5	4	10
Access Distance	5	7	4	7	7	1	7	8	3
Journey Comfort	6	12	7	6	13	10	11	11	10
Traffic Congestion	2	3	3	5	8	7	4	6	2
Risk from motorized vehicles	7	4	6	8	3	2	6	3	8
Bicycle Lane	10	9	12	12	1	6	8	11	4
Bicycle security	3	2	2	3	7	5	2	2	6
Bicycle parking facility	4	8	5	9	4	4	9	7	7
Bicycle Maintenance	9	6	8	4	5	11	3	5	5
Bicycle Rental Charge	13	11	11	10	12	12	10	13	11
Bicycle Rental Deposit	12	10	10	11	10	9	12	9	12

8. Conclusion

In this study, a scientific methodology for analysis of user perception towards a set of key determinants influencing bicycle-metro integration in typical Indian context has been demonstrated with Hyderabad, an Indian metropolitan city as a case study. Initially, a relevant set of factors are identified from a detailed literature review and user perception towards them were collected in a typical Likert scale. Subsequently, Kruskal-wallis H-test was adopted to elicit the difference in user perception and RIDIT analysis was used to compare the factor rankings across various socio-economic sub-groups. Based on the results of the study, a number of conclusions can be made:

Firstly, based on the findings of this study, it could be concluded that weather condition is the most significant deterrent influencing commuter's choice decision whether to use the bicycle mode or not. Among other factors, Bicycle safety and security at station, threat from mixed traffic towards metro, access distance to metro were highly rated determinants by all user groups alike. On the other hand, factors such as bicycle rental charge and bicycle

Peer-review under responsibility of WORLD CONFERENCE ON TRANSPORT RESEARCH SOCIETY

maintenance were rated as less important deterrents compared to the other factors, stating against the general opinion that bicycle is used because of its cost effectiveness alone.

Secondly, based on the results of Kruskal-Wallis H-Test, it can be concluded that there is a significant statistical difference on user perception towards a set of attributes influencing bicycle-metro integration in typical Indian context across different user groups.

Thirdly, this study also provides a successful application of RIDIT towards analyzing user perception towards identification and prioritization of key set of determinants influencing bicycle-metro integration. Results of this study indicate that RIDIT could be employed in similar settings for better decision making.

Fourthly and most importantly, it could be concluded that if necessary infrastructural measures are taken for improvement of key attributes, users would be willing to use the combined bicycle-metro mode for commute. The results of this small-scale study could be used as an initial input of planning for typical Indian context.

One of the major limitations of this research lies in the relatively lower sample size, which may not truly represent the population in consideration. As a future scope of the study, authors plan to conduct a more detailed study with large sample size for better representation of the population. Finally, authors would like to state that although this research has sought to demonstrate a scientific methodology to analyze user perception towards a set of attributes that influence bicycle choice specifically related to bicycle-metro integration in Indian context, the results may not be applicable to all cities of similar sizes, as urban character is known to differ significantly even in regions with similar socioeconomic settings. Nonetheless, the attributes identified and the methodology proposed in this paper is postulated to be representative of similar cities in developing countries.

References

Bachand-Marleau J., Larsen. J, El-Geneidy. A. 2011. Much anticipated marriage of cycling and transit. How will it work? Transportation Research Record: Journal of the Transportation Research Board Issue- 2247, 109-117

Betty J, and Toothaker, E. 1974. An empirical comparison of the ANOVA F-test, normal scores test and Kruskal-Wallis test under violation of assumptions. Educational and Psychological Measurement 34.4, 1974, 789-799.

Bikash. R.D, Pravat. S.K. Sreekumar. 2010. Factors Influencing Purchase of 'NANO' the Innovative Car from India-An Empirical Study. Asian Journal of Business Management 2(3): 48-56.

Bross, I. D. J. 1958. How to use RIDIT analysis. Biometrics, 14(1), 18–38.

Chang, H. L., Chang, H. W. 2005. Comparison between the differences of recreational cyclists in national scenic bikeway and local bike lane. Journal of the Eastern Asia Society for Transportation Studies. 6, 2178–2193.

Goh, K. C., Currie, G., Sarvi, M., Logan, D. 2014. Experimental Microsimulation modeling of Road Safety Impacts of Bus Priority. In Transportation Research Record: Journal of the Transportation Research Board, No. 2402, Transportation Research Board of National Academics, Washington, D.C., 9-18.

Heinen. E and Bohte. W. 2014. Multimodal commuting to work by public transport and bicycle. Transportation Research Record: Journal of the Transportation Research Board (2468), 111-122.

Lopez-Zetina, J., Lee, H., and Friis, R. 2006, The link between obesity and the built environment. Evidence from an ecological analysis of obesity and vehicle miles of travel in California. Health & Place, 12(4), 656-664.

Majumdar. B.B, Mitra. S. 2015. Identification of factors influencing bicycling in small sized cities: A case study of Kharagpur, India. Case studies in Transport Policy (3), 331-346

Parkin, J., Wardman, M., Page, M. 2008. Estimation of the determinants of bicycle mode share for the journey to work using census data. Transportation, 35(1), 93-109.

Pucher J., Korattyswaroopam N., Ittyerah, 2004. The Crisis of Public Transport in India: Overwhelming Needs but Limited Resources. Journal of Public Transportation, Vol. 7, No. 4

Pucher. J., Buehler. B. 2009. Integrating Bicycling and Public Transport in North America. Journal of Public Transportation, Vol. 12, No. 3, 79-104.

Rietveld. P, 2000. The accessibility of railway stations: The role of the bicycles in Netherlands. Transportation Research Part D 5 71-75

Sadhukhan, S., Banerjee, U. K., Maitra, B. 2014. Commuters' perception towards transfer facility attributes in and around metro stations: experience in Kolkata. Journal of Urban Planning and Development, 141(4), 04014038.

Selvin, S. 1977. A further note on the interpretation of ridit analysis. American Journal of Epidemiology, 105(1), 16-20.

Shiftan, Y., Kaplan, S., Hakkert, S. 2003. Scenario building as a tool for planning a sustainable transportation system. Transportation Research Part D: Transport and Environment, 8(5), 323-342.

Vargha, A, and Delaney. H., 1998. The Kruskal-Wallis test and stochastic homogeneity. Journal of Educational and Behavioral Statistics 23.2, 170-192.