SUSTAINABLE PUBLIC TRANSIT SYSTEM FOR LAST MILE CONNECTIVITY TO MAJOR WORK CENTRES AND THE MODE CHOICE OF EMPLOYEES

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ABSTRACT

Mostly public transit is not designed to provide a door-to-door connectivity unlike personalized modes of transport and improving the availability of feeder modes will make the public transit more accessible and attractive. Access and egress are the weakest links in public transport and this constitute a major chunk of the total travel time of a commuter. A well designed public transit system incorporating eco-friendly feeder modes also, could improve the Last Mile Connectivity (LMC) to the work centres and can create a positive spiral whereby the ridership of public transport increases, its financial viability also improves and the environment goes greener. Prior to any infrastructure planning it is essential to study the user's behavior and preferences for ensuring the viability and effectiveness of implementation. Mode choice forms an integral part of this process as it gives a complete insight to the mode choice preferences of the commuters. This research paper details on the traffic and travel characteristics and the mode preferences of two major workcentres in Kerala i.e. Information Technology (IT) campuses of Technopark in Trivandrum and Infopark at Kakkanad, both of them being major trip attraction centres. Socio economic and travel characteristics of the commuters to the work centre are analysed based on a comprehensive data collected by conducting surveys. Choice of commuters for varied modes of feeder service for last mile trip is inferred based on the user preference surveys conducted. Mode choice modeling is attempted based on a ranking approach for different mode choices in a scenario where different modes of feeder service co-exist.

KEYWORDS:

Public transit system, Sustainable transport, Last mile connectivity, Mode choice, Multinomial Logistic Regression

INTRODUCTION

Work centre campuses are found to be one of the major attraction points of commuters in an urban or sub urban area. Commuters to the high profile campuses like Information Technology (IT) parks are mostly opting to personalized modes of transport due to reasons like increased vehicle ownership, absence of a reliable and comfortable public transit system, inadequacy of last mile connectivity to final destinations etc. The Working Group on Urban Transport for the 12th Five Year Plan (FYP) precisely sums up the present scene of urban transport across India as categorized by sprawling cities, declining share of public transport and non-motorised transport, focus on supply side yet with low investments, sheer neglect of pedestrians, cyclists and public transport users and an increased motorization leading to pollution and high road fatalities/injuries (*1*). The possibility of promoting public transport facilities to this work centre campuses has to be explored as futuristic measure towards sustainable transport (2). An integrated public transport facility should be planned for such trip attraction centres with adequate provision for greener and sustainable modes for Last Mile Connectivity (LMC) and such planning process demands a thorough understanding of mode choice behavior of commuters. A proper analysis of the mode choice decisions can help in addressing issues such as forecasting demand for new modes of transport, mitigating traffic congestion, allocating resources, examining the general efficiency of travel, and will provide insight into the traveler's behavior characteristics. Mode choice analysis is the process of arriving at a decision about the mode availed of by the commuters in a particular set of circumstances or transport scenario (*3*). A commuter having a choice for mode of transport perceives different weights of disutility for the components of competing alternative modes in comparison with his own mode. Based on the totality of these weights, a commuter decides that mode which has the least disutility (*4*). Mode choice models for last mile trip also form a critical part in analysing the travel demand by commuters. A ranking approach for mode choice is adopted in this study during the data collection and analysis.

OBJECTIVES OF THE STUDY

Provision of reliable and adequate LMC options will enhance the patronage of public transit system and may result in shift of some of the personal mode users to public transport. This study is intended to analyze the travel choice of employees of a major work centre and ascertain a probable shift in their travel modes if reliable systems of sustainable modes of LMC options are available. The main objectives of this study are:

- Appraisal of existing traffic scenario inside the IT campuses
- Review of existing travel pattern and trip making characteristics of the IT professionals
- Ascertaining of existing mode choice behavior of employees working in the IT campuses of Technopark and Infopark
- Assess the factors influencing the mode choice for last mile trip to the work centres under consideration
- Proposing a sustainable scenario for improved last mile connectivity to these IT campuses with the design of fleets for operation
- Formulation of mode choice model for modal shift and ranking of choice or preference for last mile connectivity using NLOGIT software

STUDY AREA

Technopark and Infopark are the Information Technology (IT) Parks located in the state of Kerala and belong to the districts of Thiruvananthapuram and Ernakulam respectively. Technopark spread over nearly 300 acres in 4 million sq.ft space is the largest information technology park in India in terms of built up area. As of 2015, Technopark has 9.33 million square feet of built-up area, and is home to over 300 companies, employing nearly 46,000 professionals. Infopark in Kochi is a recently developed IT park by Govt of Kerala and is located in 100.86 acres of land at Kakkanad village of Ernakulam district. Around 80 acres has been notified as an IT sector Specific Economic Zone by Ministry of Commerce, Government of

India. When Infopark Kochi Phase-I is fully developed a total super built-up area of 4.50 million sqft would be completed. These campus include amenities such as food courts, banking counters, ATM, shopping arcade, etc.and is fast growing potential destination of employers at Kochi. Hence the planning of infrastructure and the various means of transportation towards this promising work centre is very significant in meeting the future mobility needs of the region. Study area map is shown in figures 1 and 2.

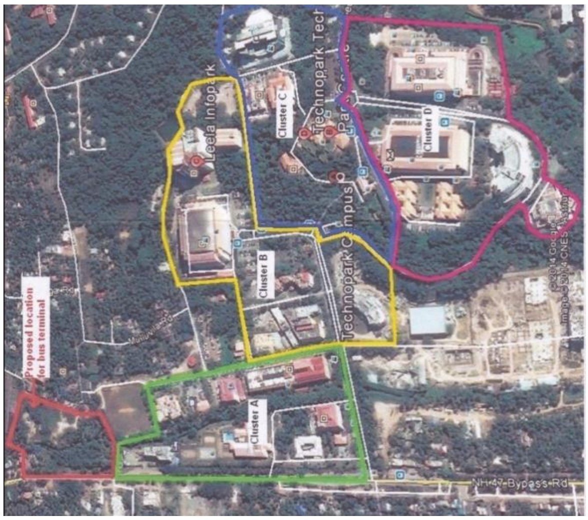

FIGURE 1 Study area - Technopark

FIGURE 2 Study area - Infopark

SIGNIFICANCE OF LMC IN MASS TRANSIT PLANNING

There is a tremendous growth in the number of employees commuting to Information Technology parks in recent times. Such IT parks even have the potential of influencing the land use of the area thereby witnessing remarkable developments. This will further lead to chronic congestion on adjacent roads due to increased use of personalized modes. The limitations of the existing public transit system are found to be a reason behind the increased modal share of personalized modes. The attractiveness of a transit as a mode depends not solely on the cost, time, comfort and convenience of the main mode but also on the quality and other attributes of the last mile connectivity. Researchers have found the connecting ends to be the weakest link and that they can significantly influence the overall appeal of transit systems given their substantial contributions in terms of travel time, cost and travel discomfort.

SURVEYS AND DATA COLLECTION

The research methodology for the study comprised of secondary data collection and primary surveys. Primary surveys comprising of categorised traffic volume counts at front and rear gates and user preference surveys (on mode choice) were conducted on a sample ofinthe campuses. Data collection of the disaggregate data was done through questionnaire survey on a sample of individual employees of the workcentre campus. The questionnaire was comprised of queries to collect personal information, vehicle information and trip information. Thus the data was collected on the socio-economic and travel characteristics of employees as well as their mode choice for last mile trip to their final destination in campus. In fact the stated preference approach has been used to analyse the response of people to hypothetical choice situations. The same approach has been adopted for model development as well. The explanatory variables considered to influence the mode choice behavior and available choice of mode were included in the questionnaire. Ranking type questions were also included for modal serviceability attributes like cost, travel time, walk and wait times. Data collection on a sample of around 5 % of the total employees on both the IT campuses was done.

DATA ANALYSIS AND RESULTS

Socio-Economic Characteristics of the Employees

Data collected were analysed to extract socio- economic and travel characteristics of the employees which may have an impact on their trip making behavior. In this study, Multinomial Logit model was considered to model the choice behavior of commuters of the workcentre and is based on the theory of utility maximization. MNL model is widely used in disaggregate mode choice model which could be used to estimate the proportion of trip makers who choose available mode types based on given conditions or utility criteria.

The user preference for last mile connectivity is found out and mode choice models formulated could evaluate the behavior of commuters of the workcentre campus and the rationale for their choice of particular modes. Also it is inferred that by and large the last mile connectivity of the workcentre campus has to be improved adequately.

After conducting comprehensive studies and surveys, a possible road map and combination of preferred modes were identified for initial implementation of greener transport in campuses and work centres and *ipso facto* leading to large scale use of greener transport modes in the state. The integration of last mile connectivity options with the existing and imminent public transport system of the region was overviewed and probed. A comprehensive database was generated on the travel behavior and choice of commuters. The potential demand of the passenger traffic and mobility requirements of employees and visitors within the campus or for their last mile connectivity to the work centre was assessed. The feasibility of deploying various feeder services for the workcentre campuses and estimation of their fleet requirement was ascertained and designed based on a rational approach. The mode choice analysis is of the users is done in detail after conducting user preference surveys. Virtuous efforts were made on mode choice modeling of the first and last mile connectivity options of the commuters to a workcentre campus.

The study has revealed interesting findings highlighting the need for providing better means for last mile connectivity in the workcentre campuses. Excerpts from the findings of the study are briefed here. Analysis of the data on explanatory variables shows the extent of their influence on travel choices of the employees. It was observed from the data of Technopark campus that the largest commuter share comes from the age group of 18 to 30 years followed by 31 to 45 years. Around 47% of employees lies in the monthly income group of Rs10,000 to 25,000 followed by 33 % with a monthly income between Rs25,000 to 50,000. It was inferred from the analysis that as income increases willingness to shift decreases. Level of education was also found significant in affecting travel mode choice but results are mixed. Most of the employees in Technopark campus are graduates (76%) followed by post graduates counting to 16%. From the analysis, it is inferred that as education level increases willingness to shift decreases. The average trip length of last mile trip of the employees is 2.3km while that of the main segment of their work trip is 12.36km. Meanwhile the average travel cost of last mile trip is Rs 28 and that of their main trip is only Rs15.7. This is quite contrasting that the travel cost per km run of last mile trip is more than 9 times that of main and longer segment of their work trip. This interesting finding itself highlights significance of this study. Also it is inferred that by and large the last mile connectivity of the workcentre campus has to be improved adequately.

The travel demand for last mile connectivity is estimated based on which the fleet design for sustainable modes of feeder services is done. The different modes preferred by the commuters comprises of solar /electric vehicles, Personal Rapid Transit system (PRT), feeder bus services, prepaid autorickshaws, cycle and the walk mode. Out of this the fleet design was done for solar /electric vehicles, Personal Rapid Transit system (PRT) and feeder bus services considering the mode and route preferences of employees of the workcentre.

Traffic and Travel Characteristics

Similar traffic and travel characteristics were observed for the employees of both the IT campuses of Technopark and Infopark. The scenario of Technopark campus is illustrated here and similar trend follows for the Infopark campus and hence it is not explained in detail. The technopark campus is having two entry/exit gates. The front main gate as well as the rear gate and each of these gates are having three peak hours of traffic flow as depicted in the figure 3. These peak hours are occurring due to the working shifts existing in the campus. The traffic composition at the front main gate of entry/exit to the campus is shown in the figures 4 which depict the increased mode share of personalised vehicles for the commuter trips to the campus. Half of the traffic inflow is two wheelers followed by cars and autorickshaws respectively. Meanwhile the traffic inflow during the same morning peak hour (8.45am to 9.45am) shows the significant share of autorickshaws followed by cars. This highlights the fact that the autorickshaws and cabs are hired for the last mile connectivity of the commuters. Similar trend is prevalent in rear gate as well. The technopark bound traffic during the peak hour of 8.45am to 9.45am is 3678 PCU and it exceeds the design service volume of 3600PCU envisaged for four lane divided arterial roads of two directional traffic. [10]The volume capacity ratio is 1.022. The study also revealed that 62% of the employees adhere to personalised modes while 26% use the public transport and 12% cling on to non-motorised transport.

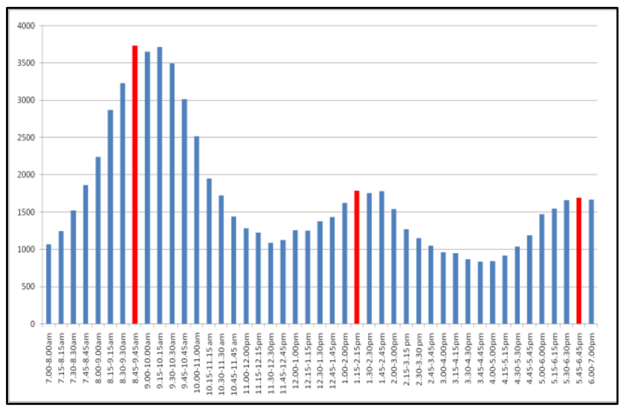

FIGURE 3Hourly variation of traffic in IT park - Technopark

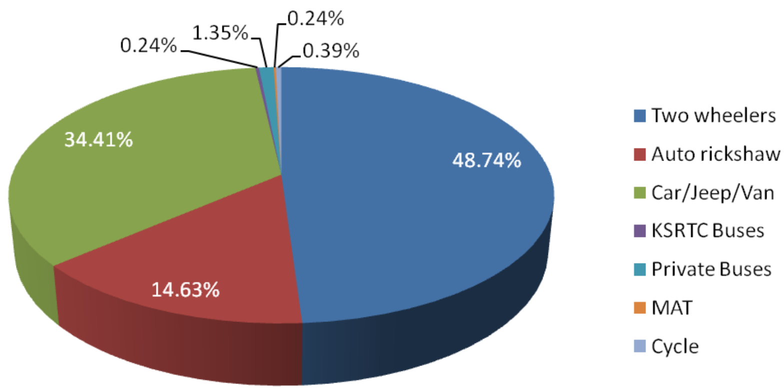

FIGURE 4 Modal share of traffic in IT park - Technopark

This survey shows that the most preferred mode for last mile connectivity is KSRTC feeder bus followed by solar/ electric /hybrid vehicles and PRT.

Average Trip Length and Travel Cost

Analysis of the data collected revealed that even though the length of main trip was higher than that of the last mile trip, travel cost of main trip is less than that of the last mile trip. Therefore, employees had to pay a higher cost to travel a smaller distance when it comes to the last mile segment of their work trip. From table 1 Technopark employees were found to spend Rs.11.06 per km for their last mile trip while the main trip cost only Rs 1.31 per km. Thus, it is clear that in the present scenario, employees spend about 8.5 times the cost of main trip for their last mile trip. The reason for this is the inadequacy of last mile connectivity and the related issues. This situation encourages the use of personalized modes of transportation. This could be rectified only by providing reliable service of last mile connectivity by means of sustainable modes with due regard to the user preferences.

TABLE 1 Comparison of average trip length and cost

Trip particulars	Average Trip Length (km)	Average Trip Cost (Rs)	Average Cost per km (Rs)
	Technopark		
Last Mile Trip	2.3	25.43	11.06
Main Trip	12	15.68	1.31
	Infopark		
Last Mile Trip	3	19.90	6.63
Main Trip	13.04	31.40	2.40

Demand Estimation and Fleet Design of LMC

Based on the analysis of data collected by secondary and primary surveys including mode choices of the users, the demand for last mile connectivity was estimated and the routes were selected and fleets were designed for the different modes of feeder service like solar/electric/hybrid vehicles, Personal Rapid Transit (PRT), Feeder bus and prepaid auto rickshaws. The study also recommends for providing segregated walk ways, other pedestrian facilities and bicycle hubs to facilitate a promising category of users of non-motorised transport (around 12%).

Route Selection and Fleet Design for Technopark

Based on the study the following routes are recommended for the Technopark campus:

- Route 1 connects buildings in the Technopark campus phase 1 with the proposed bus terminal near the campus. This route could be utilized by the modes like solar vehicles, PRT and bus
- Route 2 connects Kazhakuttam railway station, Kazhakuttam junction and proposed bus terminal with Technopark campus
- Route 3 connects Kazhakuttam railway station to the Technopark campus

Average speed of PRT is taken as 30kmph while that of solar vehicle as 35kmph and that of feeder buses as 49kmph. A modal shift of 20% (optimistic scenario) from personalized mode (car or two-wheeler) to public transport is considered while estimating the demand.

The fleet design is carried out for the selected routes and is given in table 2.

TABLE 2 Fleet Design for Last Mile Connectivity in Technopark Campus

Total no. of vehicles required	No. of vehicles required in one set	Demand* frequency	Demand in an hour	Number of sets	Frequency (min)	Time to complete one trip (min	Stops	Length (km)	Vehicle type	Route
4	2 (14seater + 23seater)	37	448	2	5	9.4	8	4.3	Solar	R1
6	3	100	858	2	7	12.3	9	6.7	Bus	
12	3	13	268	4	3	11.3	5	5	PRT	R2
3	1	44	376	3	7	20.3	9	12	Bus	
4	2 (7seater + 14seater)	18	210	2	5	10.9	8	5.2	Solar	R3
			2160							

As derived in the table the vehicle requirement for the fleet operation is as follows:

Number of PRT vehicles required = 12 five seaters

Number of solar vehicles required = 2 seven seaters, 4 fourteen seaters, 2 twenty three seater

Number of feeder buses required = 9 forty two seaters

The sample of routes selected for the feeder service to provide last mile connectivity in Technopark campus is as shown in figure 5.

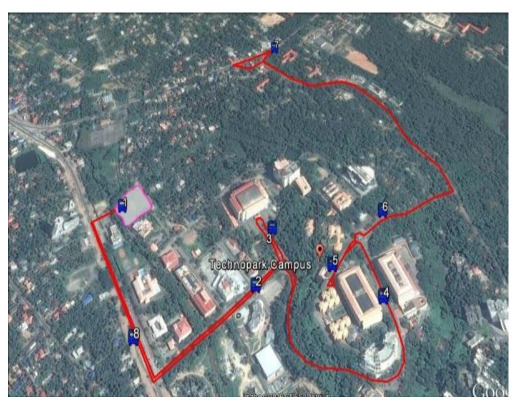

FIGURE 5 Routes selected for feeder service in IT park - Technopark

Route Selection and Fleet Design for Infopark

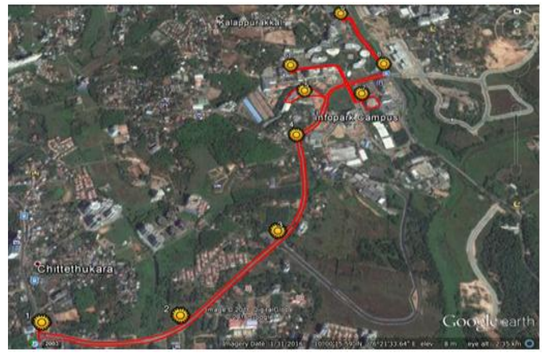

FIGURE 6 Routes selected for feeder service in IT park - Technopark

Fleet of vehicles required for last mile connectivity are estimated for the demand during peak hour. Total demand of person trips to be catered during the peak hour is considered for fleet design. It is assumed that the vehicles can maintain an average speed and that each stop would require 15 seconds for boarding and alighting. Routes for operation of last mile connectivity services were selected based on the analysis of travel details of commuters to the campus. Solar vehicles and feeder buses were considered as the options for last mile connectivity in Infopark campus. There is a proposal for the extension of imminent metro rail services through Infopark campus in its second phase.

The route selected connects buildings in the Infopark campus phase 1 with the three points- Kakkanad bus stop, Infopark main gate and Seaport-Airport road. This route could be utilized by the modes like solar vehicles and buses. Solar cars start from the Kakkanad Bus stop, connect each building inside the Infopark campus and extend upto Seaport-Airport road. It takes the same path through the campus in its return journey and reaches the Kakkanad bus stop. It is the only one logical and practical path that can be adopted to reduce traffic congestion inside thecampus.Trip length of route covered by solar car is 10.32 km. 7 numbers of stops are provided inside the campus. It takes about 22 minutes to complete one trip.

The fleet design is carried out for the selected routes and is given in table 3.

TABLE 3 Fleet Design for Last Mile Connectivity in Infopark Campus

Total no. of vehicles required	No. of vehicles required in one set	Demand* frequency	Demand in an hour	Number of sets	Frequency (min)	Time to complete one trip (min)	Stops	Length (km)	Vehicle type
8	2	37	442	4	5	22	9	10.32	Solar
6	3	121	1033	2	7	20	9	10.32	Bus
			1475						

As derived in the table the vehicle requirement for the fleet operation is as follows:

Number of solar vehicles required = Four sets of 2 seven seaters/ one fourteen seaters and 1 twenty three seater

Number of feeder buses required = 6 forty one seaters

MODEL DEVELOPMENT

Shift from personalized mode to public transit

The probable shift from personalized mode to public transit was estimated using binomial logit modeling in a scenario where reliable last mile connectivity is provided. The model calibration results are shown in Table 4. It can be seen that the signs of the parameters of the variables like travel cost and time are logical and the variable travel time has more significance in determining modal shift than travel cost. The parameter estimate of travel time is significant at 5% level.

TABLE 4 Model Calibration for Modal Shift

CHOICE	Coefficient	Standard Error	z	Prob. |z|>Z*	95% Confidence Interval	
TT	-.05915**	.02666	-2.22	.0265	-.11140	-.00690
TC	-.00790	.03664	-.22	.8292	-.07972	.06392
A_PERSON	-2.37110**	1.05432	-2.25	.0245	-4.43752	-.30468
PER_INC1	.55461**	.27269	2.03	.0420	.02014	1.08908
PER_DIS1	.07712*	.04400	1.75	.0797	-.00912	.16336
Note: ***, **, * ==> Significance at 1%, 5%, 10% level.						

Mode choice for LMC

The user preference for last mile connectivity is found by a stated preference survey and mode choice models were attempted to evaluate the behavior of commuters of the workcentre campus to choose the particular mode. Work based last mile connectivity mode choice analysis was carried out using NLOGIT software, development of model is done in multinomial logit form. Multinomial logit modelling for last mile connectivity based on wait time (WTT), journey time (JT) and travel cost (TC). The coefficients of all the parameters have a negative sign indicating that, as the wait time, journey time or travel cost increases, they are less preferred. Among the coefficients obtained from the analysis, the coefficient of wait time is the largest indicating that it influences the mode preference more than the other two parameters.

Mode choice analysis ranking preference of last mile connectivity modes of work based trips of employees of IT campuses in Kerala was carried out using NLOGIT software, development of model is done in multinomial logit modeling. The general expression for the probability of choosing an alternative ‘i’ (i=1, 2, 3...., j) from a set of j alternatives is:

$$\mathbf{Prob(y_i=j)=exp(\beta' x_{ij})/(\Sigma^{j}_{m=1}\, exp(\beta' x_{im})}$$

NLOGIT is built around estimation of the parameters of the random utility model for discrete choice,

U (choice j for individual i) = $U_{ij} = \beta_{ij}'\mathbf{x}_{ij} + \varepsilon_{ij},$ j=1,....Ji,

in which individual i makes choice j if Uij is the largest among the Ji utilities in the choice set. The essential commands for the set of discrete choice models in NLOGIT are the same for all, with the exception of the model name:

Model; Lhs= variable which indicates the choice made
; Choices= a set of J names for the set of choices
(utility functions)
; Rhs= choice varying attributes in the utility functions
; Rhs= choice invariant variables, including one for ASCs $
(or)
; Model: utility specifications.....$

Following table represents the results of the multinomial logitmodelling for last mile connectivity based on wait time (WTT), journey time (JT) and travel cost (TC). The rank given by employees is taken as the RHS. The coefficients of all the parameters have a negative sign indicating that, as the wait time, journey time or travel cost increases, they are less preferred. Among the coefficients obtained from the analysis, the coefficient of wait time is the largest indicating that it influences the mode preference more than the other two parameters. A1,A2,A3,A4,A5,A6 are the alternative specific constants for the model.

```
Discrete choice (multinomial logit) model
Dependent variable              Choice
Log likelihood function     -7589.14973
Estimation based on N =    1110, K =    9
Inf.Cr.AIC  =  15196.3 AIC/N =    13.690
Model estimated: Apr 21, 2016, 15:25:24
Model estimated using RANK data for LHS.
Constants only model must be computed directly
To compute pseudo RSQ, use NLOGIT ;...;RHS=ONE$
Number of obs.=  1110, skipped    0 obs
```

RANK	Coefficient	Standard Error	z	Prob. |z|>Z*	95% Confidence Interval	
WTT	-.02897***	.01032	-2.81	.0050	-.04921	-.00874
JT	-.00305**	.00142	-2.16	.0310	-.00583	-.00028
TC	-.00317**	.00147	-2.16	.0309	-.00604	-.00029
A_1	1.10133***	.08584	12.83	.0000	.93309	1.26957
A_2	1.79746***	.07099	25.32	.0000	1.65833	1.93659
A_3	1.76161***	.07330	24.03	.0000	1.61795	1.90527
A_4	2.01502***	.08093	24.90	.0000	1.85640	2.17365
A_5	-.18926*	.10138	-1.87	.0619	-.38796	.00944
A_6	-.78549***	.11587	-6.78	.0000	-1.01258	-.55839

Note: ***, **, * ==> Significance at 1%, 5%, 10% level.

The models are found to be statistically significant with satisfactory rho-square values of 0.2.

The following models were developed using the output of trial 1. U (1), U (2), U (4), U (5), U (6) are the models for an Infopark employee for ranks 1, 2, 3, 4, 5, 6 respectively.

U (1) =1.10133-WTT*.02897-JT*.00305-TC*0.00317

U (2) =1.79746-WTT*.02897-JT*.00305-TC*0.00317

U (3) =1.76161-WTT*.02897-JT*.00305-TC*0.00317

U (4) = 2.01502-WTT*.02897-JT*.00305-TC*0.00317

U (5) =-0.18926-WTT*.02897-JT*.00305-TC*0.00317

U (6) =-0.78549-WTT*.02897-JT*.00305-TC*0.00317

CONCLUSION

This paper provides an overview of the integration of last mile connectivity options with the existing and imminent public transport system of the region. The travel behavior and choice of commuters are studied in detail. The potential demands of the passenger traffic and mobility requirements of employees and visitors within the campus for their last mile connectivity to the work centre are assessed based on the data collected by primary surveys. The feasibility of deploying various feeder services for the workcentre campuses is ascertained and the fleet requirement is estimated. The mode choice analysis is of the users is done in detail after conducting user preference surveys. The study has revealed interesting findings highlighting the need for providing better means for last mile connectivity in the workcentre campuses.The main parameters that influence the traveler to choose a mode are waiting time, travel time and travel cost. As the wait time, journey time or travel cost of the mode increases, they are less preferred. Waiting time influences the mode preference more than the other two parameters. Also age, distance monthly income, gender, education also influence the mode choice.The study proposes that a scenario encompassing different modes of feeder service like solar/electric/hybrid vehicles, feeder bus, prepaid auto rickshaws, personal rapid transit (prt), bicycles etc as alternative options for LMC would pave way for increased patronage of public transport thereby leading to promotion sustainable public transit system.

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