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Planning proposal for green mobility based of users perception to cater last mile connectivity: An Indian experience

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Abstract— **the public bicycle sharing system (PBSS) is considered as the most sustainable non-motorized transportation system. For the execution of the PBS system in the study area(East zone) of Surat city, this research paper discusses the planning and application of the Public Bicycle Sharing System by integrating with the Public Transportation system and providing free or fare based access to a bicycle for the particular study area. By performing Field surveys and analyzing the collected data, major stations with potential demand areas like high population density, activity centers, and public transport stations are recognized. An accessibility analysis was carried out to calculate the volume of activity to which a major station has access. Drawing upon a review of people this Project targets to build the evidence base to increase our understanding of PBS implementation as an important first step in planning for a low-carbon society. The purpose of this system is to make a mind-set of adopting pollution-free transport which will consequently lead to a reduction in carbon footprint. This study also provided a calculation of carbon footprint reduction in a whole year if PBSS will implement in the study area.**

I. INTRODUCTION

It is a bitter truth that with the development of cities, the world is in front of numerous issues like traffic congestion and environmental pollution. Therefore, the adoption of the GREEN transport system to overcome or shrink the crucial influences of such issues is imperative. Hence, the administration tries to attract commuters towards sustainable transport to sort out these difficulties. One of the attempts in developed and developing countries is the implementation of a public bicycle sharing system in their urban area. Public bicycle sharing (PBS) system is a flexible form of transport that comprise of a dense network of the cycle on a rental basis (Sun et al. 2017) (Fishman, Washington, and Haworth 2012). Bicycle sharing permits users to use bicycles on an as required purpose apart from costs and responsibility related to owing it (Feng and Li 2016).

As per the bike-sharing world map as on Dec.2017, there are more than 370 cities functioning bicycle sharing systems in addition to around 250 being planned in more than 30 nations(Patel, Patel, and Joshi 2019). Approximately, 0.6 Million bicycle fleet operated around the globe as in 2017(Patel, Patel, and Joshi 2019). Developing countries like China also have implemented the PBS system, but they are facing issues regarding less ridership (Feng and Li 2016) (No Title 2011). Even in India PBS system has been implemented in 15 cities under smart city missions, but a majority of them have issues of less ridership (Patel, Patel, and Joshi 2019). Numerous factors are documented for the less ridership includes the habit of personalized mobility option, limited docking station, an unplanned network of bicycle lanes, and missing connectivity with public transportation(Campbell et al. 2016). Besides this, India also has the potential to escalate PBSS ridership if these factors are dealt with before planning the PBSS (Campbell et al. 2016). At the planning stage, if the city administration knows the peoples willing to use, pay, and probable mode shift to the PBSS then they could make strategy accordingly. Therefore, the present study is carried out House-hold (HH) survey to know insights of user's perception of the planning and design of PBSS.

The prime motive of the study is to understand the present mode share scenario, activity pattern, and societal status of residents of the study area of Surat city and based on that analysis planning of PBSS is proposed (Yang et al. 2016). For the study total, 254 valid surveys were taken through a survey form. This leads to analyze data more efficiently and provide the right information of commuters. A total of 35 questions were asked to users in questionnaires to get different information such as demographic data, the origin-destination pattern of the trip, willingness to use(WTU), willingness to shift(WTS), and willingness to pay(WTP) for PBS service, etc.(Yang et al. 2016). The number of survey sample depends upon variation of density, area, and population of each ward in the study area. These Collected data further analyzed concerning ITDP (Institution for Transportation and Development Policy) guidelines. The location of the docking station is decided based on optimizing different layers obtained through survey analysis of O-D pattern, public transit stop, Intra para-transit stops, willing to walk for a docking station, willing to ride a bicycle, etc. in ArcGIS software. Final locations are classified as small, medium, and large docking stations according to their observed demand.

Finally, based on probable trip generation and mode shift scenarios, the impact of reducing carbon footprint, CO_2 emission, and carbon credit are measured. Moreover, the financial aid received through the trading of carbon credits will help to cultivate sustainable infrastructural projects in urban areas. This framework will help city administration to utilized available financial possessions in an optimum way to developed PBSS as well as enhance the cities live ability and quality of life.

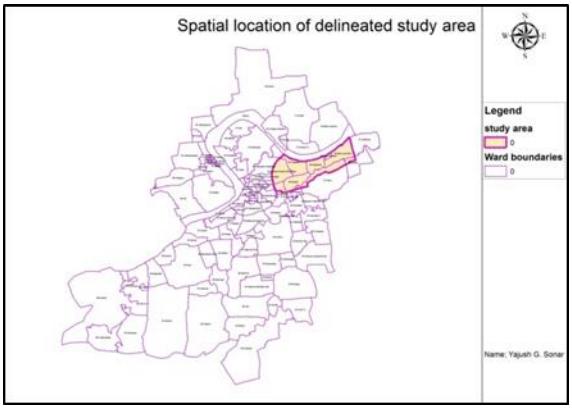

Figure 1City level location of study area

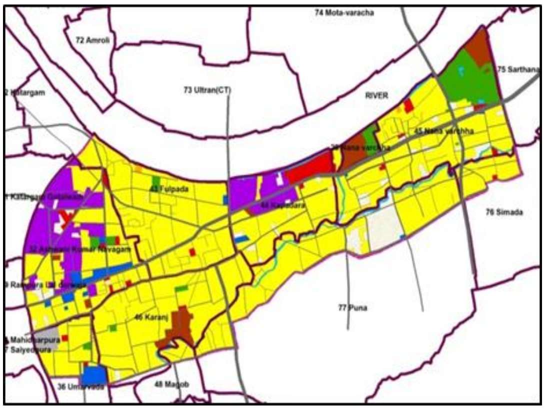

Figure 2 Existing land use map of study

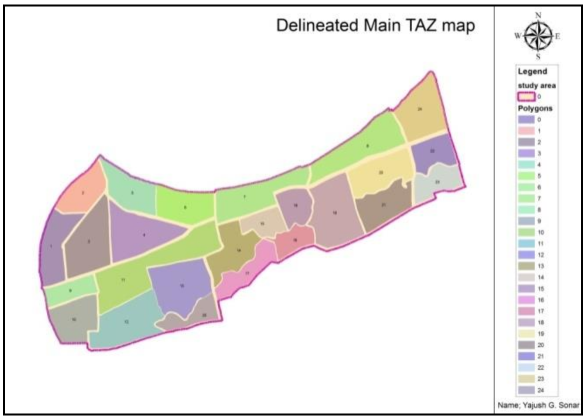

Figure 3: Main TAZ map

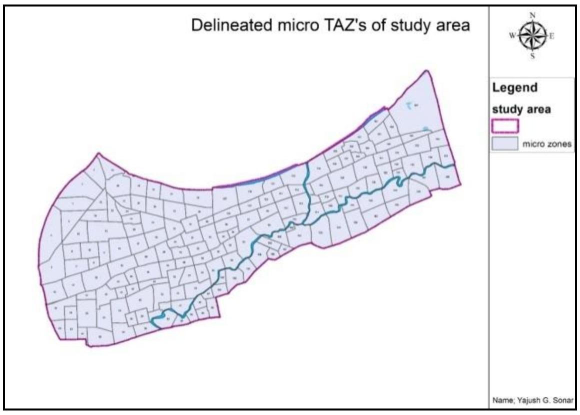

Figure 4: Micro zones map

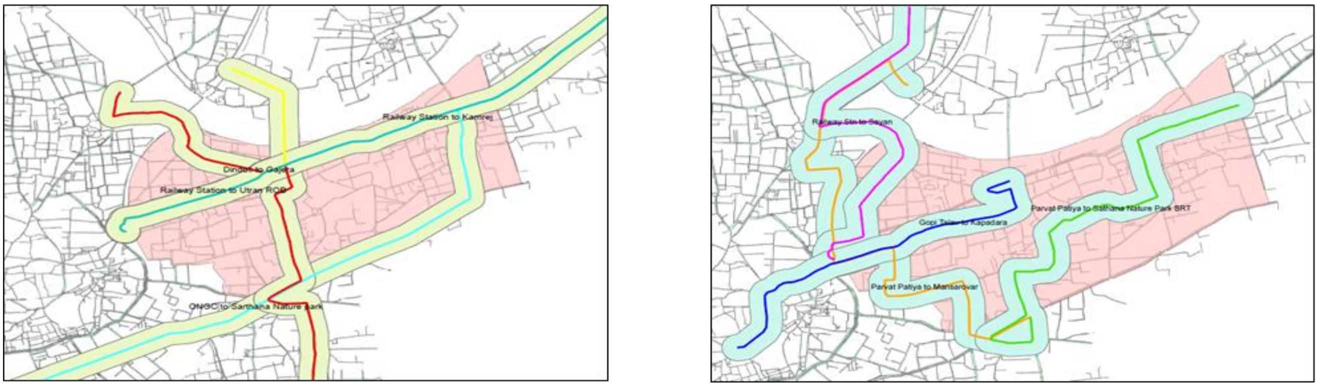

Figure 5 Existing BRTS Routes and City Bus route in Study Area respectively

II. Study Area Profile

The present study is focused on the Varachha area of Surat city- an important industrial hub and commercial center of the country. With a growth rate of about 4.9 %, there are also growing infrastructure and transportation requirements that need to be met. The nature of land use existing in the east zone of Surat city has led congestion on the urban radial road of Railway station to Kamaraj due to the concentration of diamond dominated industrial and commercial activities and another major mixed type of land-use development. Hence the BRT corridor identified along the central spine has to be fed with an efficient feeder system for its improved ridership. The delineated study area is as demonstrated in fig. 1 regarding the location from fig. 2. The study area delineation is carried out based on criteria such as Existing transportation facilities and it's influential (command) area, the hierarchy of road networks, administrative boundaries, population density, physical geography, natural barriers, socio-economic data and boundary compatibility comprising of 10 census wards partly with a total area 13.572 sq.km. At the disintegrated level, on the lines of the objective stated, a subject area with cordon line is further sub-divided into two tiers, viz. macro level and micro level. 25 number of TAZ's are delineated for data collection and study of travel pattern of inter-zonal and intra-zonal trips following its sub-division into 167 microzones based on a criterion to fetch additional trip concentration, to conform block size adhering standard walkability of 400m focusing at societal/block level as shown in Fig. 3 and 4.

A. BRTS Route in Study Area:

- Sarthana Nature Park to Amazia Park (7.6 Km)
- Railway Station to Sarthana nature park (8.7 Km)
- Gaushala Fulapada to Amazia amusement park (7.6 Km)

B. City Bus Route in Study Area:

- Kapodara to the railway station (4.4 Km)
- Parvat patiya to Sarthana nature park (8.7 Km)
- Fulpada to Railway station (3 Km)
- Parvat patiya to the railway station (5.3 Km)

III. Methods

The framework of suggested work, as shown in the flow diagram represents a method of the study carried out. Needs for the study is defined based on the O-D survey and analysis of weakened conditions of the present transportation system in selected study part of Surat city. Key objectives are derived with methodology, and expert belief is decided accordingly. A review of associated research with common ideas is studied in detail. The travel numbers required for the development of such a logical process are collected using a casual sampling approach. The same data is fed to MS excel for its primary study. Provision of physical boundary for study area done with the help of Arc GIS software. Google earth software also helped in suggesting each proposed docking station in the study area with the help of ITDP (Indian transportation & development policy) guidelines. Travel demand predicting involving trip generation to traffic assignment is carried out based on the estimated population and collected data of origin-destination. Analysis of results is used as fundamental to frame out transport policies, and the proposal is designed accordingly. The questionnaire was used for passenger surveys. The following data were collected in an online questionnaire from each respondent:

- The mode of transport used by the user for his/her purpose e.g. Walk, bus, car, private vehicle.
- The respondent's background including age, gender, household income, occupation
- Trip characteristics like duration of the trip, length of trip, frequency of trip.
- Distance and location of the docking station as per user perception.
- The enthusiasm of people towards PBS system adoption.
- The readiness of users for fare base service.

IV. Analysis

Discernment of citizens with household (HH) surveys must be needed for the practicality of the PBS system. So HH survey was carried out to understand human perception, travel patterns, and demand of the east zone of Surat city. The analysis in this study combines data from web questionnaires provided to commuters at various locations across the east zone. The survey was carried out in different phases from August to September 2018. In the first phase, a survey was taken along the BRTS route of east zone followed by survey along the city bus route, and Auto rickshaw stands in the second phase. The catchment area (area away from BRTS and City bus route) survey also has been carried out in the last phase. Total of 254 valid survey responses considered for analysis among 300 responses. Responses considered invalid if any necessary details are to be found incorrect or missing. The important characteristic of this survey is that it was conducted during peak hours to get actual peak hour traffic patterns. Analysis of below significant parameters gives an impression of the suitability of this sustainable non-motorized system in the east zone.

Table 1 shows a description of various factors along with mean. The mean age of the respondents is 28.31 year. HH income is the annual income of the respondents, the mean value is 29,640 INR (425 USD). Distance travel by bicycle and distance of docking stations are the distance that user can travel with bicycle and distance of proposed station for locating bicycle after completion of his/her purpose respectively. A smart card is the advanced model of payment that integrates the PBS system with BRTS and the City Bus route. The mean value for the smart card is around 687.04 INR (10 USD) per month.

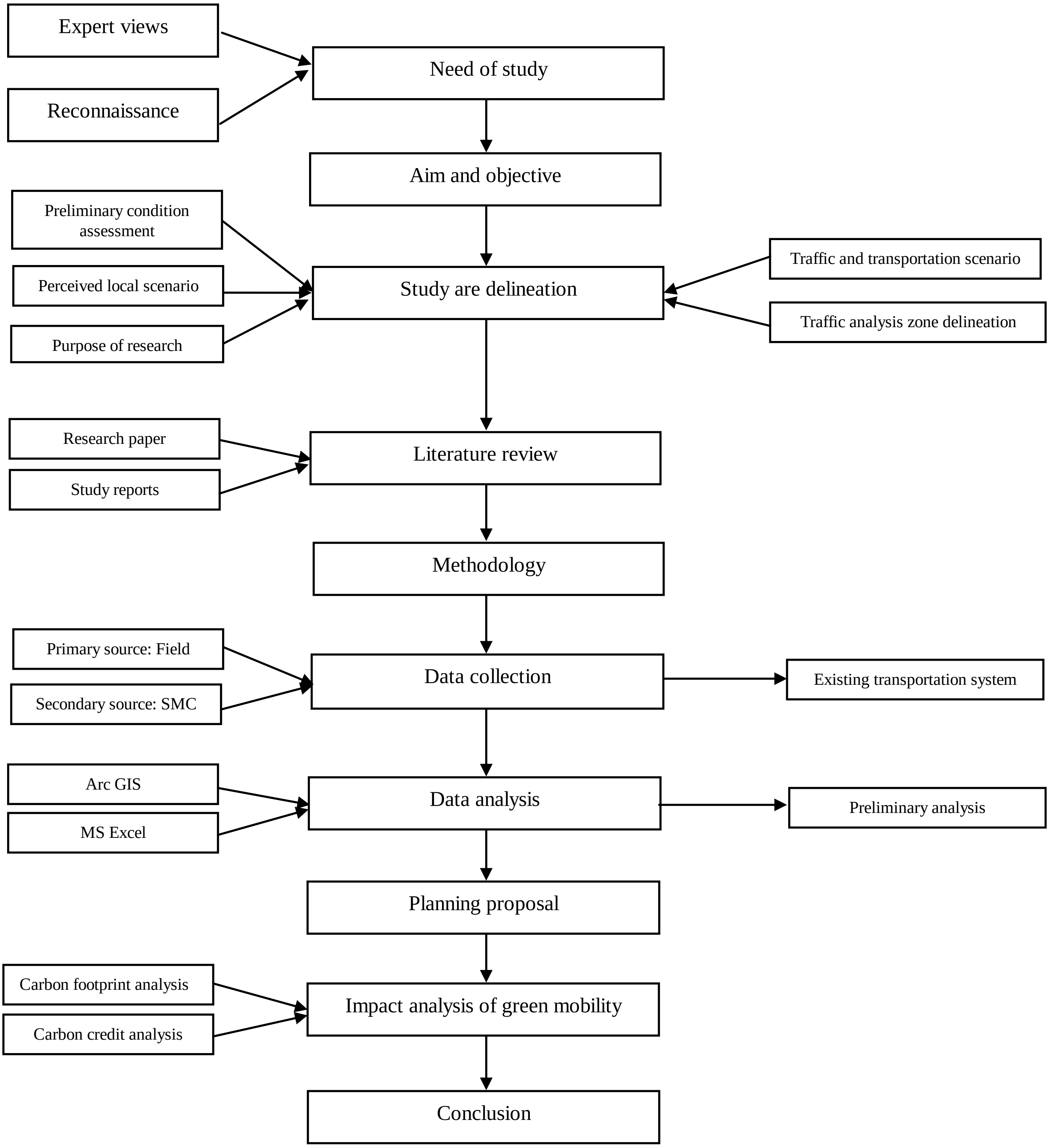

Fig 6. Methodology Flow Chart

Table 1 Parameter Analysis

Variable	Description	Value	Mean
Number of Respondents	Total	300 (254 valid)	
Age of Respondents	Range In Years		
	13-20 yr.	19.84(%)	28.31 yr.
	21-30 yr.	43.25(%)	
	31-40yr	25.4(%)	
	41-50 yr.	9.92(%)	
	>50 yr.	1.59(%)	
HH income	<10000 INR	1.97(%)	29.64 k INR (425 USD)
	11000-20000 INR	16.14(%)	
	20000-30000 INR	38.98(%)	
	30000-40000 INR	27.95(%)	
	40000-50000 INR	6.3(%)	
	> 50000 INR	8.66(%)	
Distance Travel by Bicycle	500 - 1500 m	69.33(%)	1460 m
	1501 - 2500 m	21.33(%)	
	2501 - 5000 m	8(%)	
	> 5000 m	1.34(%)	
Distance of Docking Station	< 100 m	44.8(%)	130.4 m
	101 - 200 m	45.6(%)	
	201-500 m	7.2(%)	
	>500 m	2.4(%)	
Cost of Transport per month	0-500 INR	17.6(%)	1226 INR (17.51 USD)
	501-1000 INR	22.8(%)	
	1001-1500 INR	20.8(%)	
	1501-2000 INR	24.4(%)	
	>2000 INR	14.4(%)	
Trip Distance	0-1 km	16.5(%)	4.45 km
	1.1-2 km	16(%)	
	2.1- 5 km	25(%)	
	5.1-8 km	22.75(%)	
	>8 km	19.75(%)	
Smart Card (Monthly Rate)	501-700 INR	62.75(%)	687.04 INR (10 USD)
	701-900	31.99(%)	
	901-1100	4.45(%)	
	1101-1500	0.81(%)	
	>1500	0(%)	

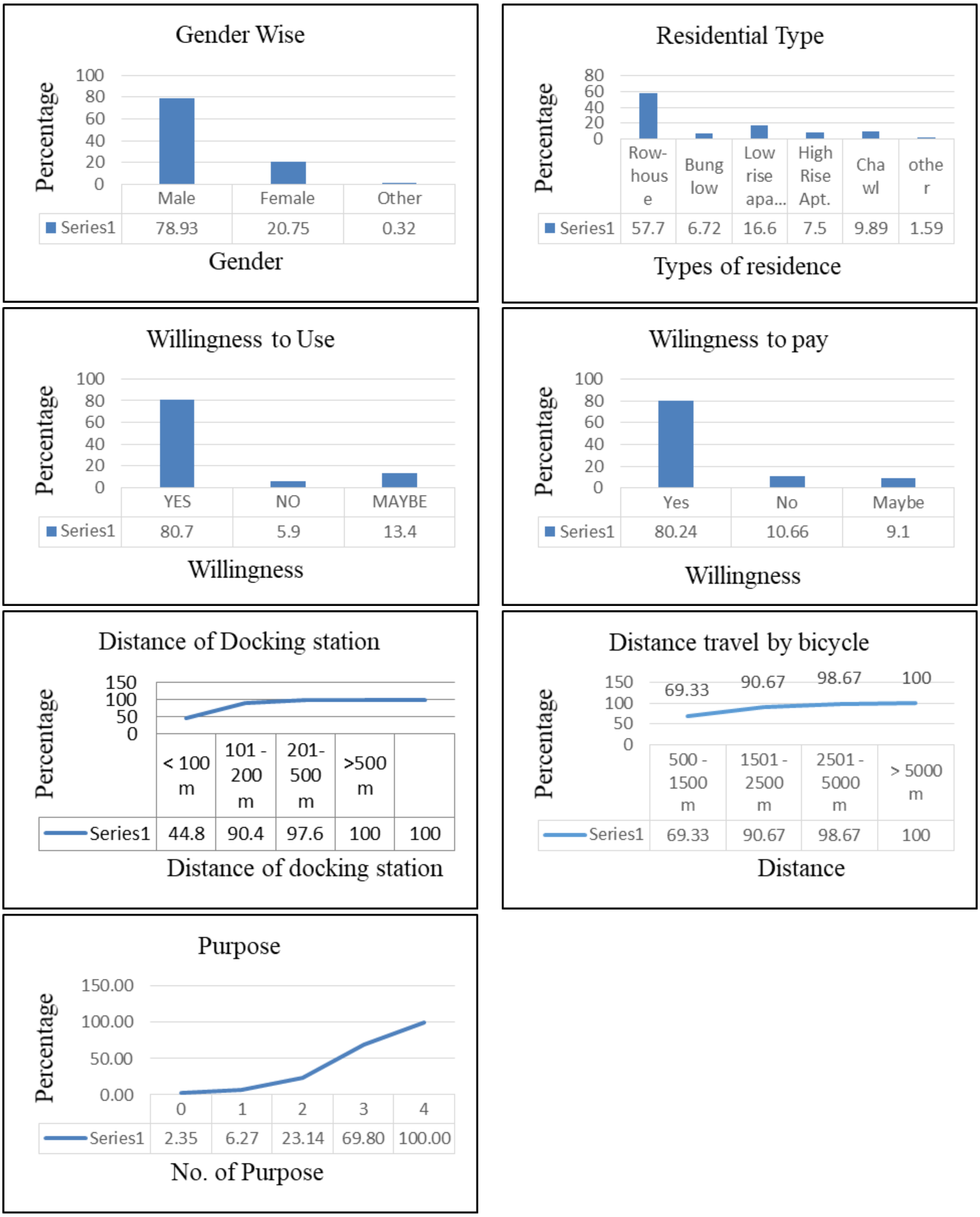

Figure 7 Graphs of Responses on different parameters

A. Gender of respondent:

It is essential to identify travel preferences based on gender. In this survey, out of 254 valid forms, 80.7 % of respondents are Male, and 20.75% are Female. That reflects very fewer women participation is in driving the different modes for traveling or they are not a frequent traveler

B. Residential type

The study indicated that 57.7% & 16.6% of respondents live in row houses and low rise apartments, respectively. Meanwhile, 9.89%, 7.5%, 6.72%, 1.59% of respondents live in Chawl, High rise apartment, Bungalow & others, respectively. That indicates the financial capacity of an individual is very less and that papered will help in the implementation of low-cost mobility.

C. Willingness to Use

This predominant factor indicates a perception of users towards PBS service. According to analyzed data, 80.7% showed readiness to adopt PBSS as a mode of travels followed by 13.4 %, who are still not sure and if proper infrastructure is provided than might be, they will use while only 5.9% are less concerned about the PBSS.

D. Willingness to Pay

Choice of PBS system over the private mode of transport, whether people are willing to pay is studied, and analysis shows that 80.24% are ready to pay the fare whereas 9.1% are uncertain because they are not in a position to use the system. Rest 10.66% are interested in free of cost system.

E. The distance of docking station

The distance of the docking station indicates how nearest is the docking station forms the user's origin and destination points. Cumulative graph analysis shows that approx. 90% of people want distance of docking station from their home or workplace in the range of 100 to 200 meters, and hence the distance of 200m from major land use can be adopted for station location.

F. Distance travelled by bicycling

Data analysis cites that mean distance people can travel with a bicycle is around 1.5 km whereas, from the cumulative graph, 90% of people stated that they can ride a bicycle comfortably up to 1.5 km to 2.5 km. It indicates that the shorter trips can be shifted to the PBSS

G. Purpose for Use

The response of respondents to use the PBS system divided into 4 purposed i.e., Work, Education, Shopping, Recreation &Others. From this, analysis it is found that more than 60% of people may use PBS for at least three purposes. So this parameter helps in finding the location or route planning for multi-destination trips. Further, the analysis of the trip generated from each of the micro-zone is carried out using the per capita trip of that zone and used as a multiplying trip factor (MTF). MTF is the ratio of the total trip in the individual zone as per the survey to the total individual's travels from that zone as per the survey. The trip generation from each of the zone is shown in Table 2.

To implement the PBS system in the east zone, the needs of total population data living in the study area of the east zone as well as traffic volume data are necessary. As per the analysis, nearly one million population will be cover by this service, and a total of 1038750 trips will occurring per day in the study area.

V. DESIGN OF PBS SYSTEM

Considering 400 m accessibility distance for walking, the public transport coverage map shows that the transportation system in the study area is ill to attract the commuters. A central spine route oriented public transit system is nowhere shifting the trip-makers from PV to PT due to several other reasons other than choice preferences. Such is the non-availability of a feeder system to stations of public transport. The stops of BRT and City buses are not fed by trip makers resulting in lesser ridership and weakens the urban public transport. It is inferred from SP survey analysis that a significant shift from private vehicles will take place if specific conditions are fulfilled such as stated access distance, frequency, and other travel improvement parameters. Other travel and transit-related is a part of operations and scheduling and traffic management policies, but the availability of mobility options right from origin to destination of a trip maker for the seamless connectivity has to be dealt by physical planning proposals and introduction of alternative solutions to feed the transit stations to achieve first and last-mile connectivity throughout the trip. Planning of such a feeder system to support the existing public transportation is an exercise carried out based on the origin-destination matrix and travel pattern in the study area considering the distribution of activity centers. Such planning involves certain steps to align the feeder services and find out the best fitting route to serve the population under its catchment area. But before this, the nature of feeder service has to be identified that would be well suited conforming to the travel behavior characteristics of the study area. By the name itself, the intermediate transport system acts as a supportive link between trip producing origins and trip attracting destinations. The planning component in such proposals is orientation and route alignments for IPT as a feeder to mass transit stations and is an exercise of optimization.

Even though, IPT auto-rickshaw is a point to point pick drop service but can have limited access to collector roads and local roads to some extent due to non-availability of road widths. It is also evident through preliminary analysis that about 85% of trips in the study area are shorter trips in order of 3.5 km. Thus at an intermediate level between public transport which is mostly meant to favor ridership for longer trip lengths and restrictions for not aligning para-transit routes at second and third levels of road hierarchy due to bad street infrastructure; a substitute for intermediate transport service can be “Public bicycle sharing system” in addition to organized IPT service. Being a Non-motorized transport (NMT) option for mobility it has several benefits over motorized options. At the global platform, public -Bicycle Sharing System (PBSS) is introduced in Amsterdam, since the ’60s. Since then it is proving to be the greenest mode of transportation for daily urban trips thus promoting low carbon mobility in the city. The principle of bicycle sharing is as simple as: "Utility without costs and responsibility of ownership on need basis". Considering the tiers of mobility right from origin to destination, it follows the system of accessibility. Owing to 85th percentile access distance of 400 m revealed from the SP survey, it is expected by the commuter to avail facility of intermediate or public transport service at a walkable distance and this is the first tier of mobility. Based on the utility of the user, he/she may transfer once or twice following the next tiers as shown in Fig. 8

area-specific opportunities to promote such kind of NMT option is the nature of compact development with higher population density. Also, mixed kinds of land use will favor the usage of PBSS. Activity centers and potential destinations for daily trips in the study area are majorly concentrated at junctions and road intersections facilitating easy accessibility and set-up of the system. Thus PBSS will attract such community and can prove to be a cost-efficient mobility option. Besides the implementation costs of the PBSS system is comparatively low and can be executed as a pilot project. NUTP 2016 guidelines do promote NMT infrastructure and are proposed. The detailed design, quantification, and planning proposal are elaborated under proposals.

Table 2 Ward wise data of East Zone

Zone No.	*Zone Name*	*Population Density*	*Survey Area (Sq. Km)*	*Survey Population*	*Multiplying Trip Factor*	*Total Trips*
32	*Ashwinikumar -Navagam*	*29236.49*	*2.11*	*61689*	*1.1*	*67857.9*
44	*Kapodara*	*40297.02*	*1.68*	*67699*	*1.15*	*77853.85*
28/45	*Nana Varachha*	*24054.84*	*3.35*	*80704*	*1.19*	*96037.76*
46	*Karanj*	*111290.81*	*1.85*	*205888*	*1.16*	*238830.08*
48	*Magob part*	*109952.83*	*0.53*	*58275*	*1*	*58275*
76	*Simada*	*9041.89*	*1.1*	*9946.07*	*1*	*9946.07*
36	*Umarwada*	*36027.71*	*0.58*	*20896.07*	*1.17*	*24448.40*
49	*Dumbhal*	*35027.48*	*0.29*	*10157.97*	*1.08*	*10970.60*
78	*Magob Extended Part*	*13914.43*	*0.32*	*4452.62*	*1.1*	*4897.88*
77	*Puna*	*47278.40*	*5.76*	*272323.62*	*1.16*	*315895.4*
43	*Fulpada*	*59462.46*	*1.89*	*112384.05*	*1.19*	*133737.02*
Total			*19.465*	*904415.41*		*1038750*

In the current scenario, only 1% of respondents from the SP survey revealed their will for the utility of public bicycles as a model for their first mile and last mile connectivity and readiness to use PBS. Also, PBSS can be used by the commuters of shorter trips as their main mode of travel. Focusing to present study area, PBSS can prove to be a better option since the network of narrow streets will not allow the motorized public transit to serve the demand. Besides providing multiple options of mobility will create an opportunity to take wise decisions maximizing their utility. Some general merits of public bicycle sharing system are list as below,

- Reduce congestion and improve air quality
- Increase accessibility
- Increase the reach of transit
- Improve the image of cycling
- Provide complimentary services to public transport
- Improve the health of the residents

Besides the above-mentioned benefits, certain study

As we know that every system to be implemented needs a specific time to assess its adaptability. Taking the existing public transportation system as fixed constant, feeder services are checked for their usage on a pilot basis. Thus policy is made to implement the system in two stages, viz. the first stage is multi-modal integrated system of public transport, newly proposed mass transit and organized IPT system along with PBSS as feeder service and the second stage consists of same existing mass transportation with only PBSS as a full-proof feeder system. At the initial stage, PBSS is planned to support IPT feeder, and later on, at the second stage, the bicycle sharing system is expected to take over ridership from IPT and cover the feeder lines with united PBSS system.

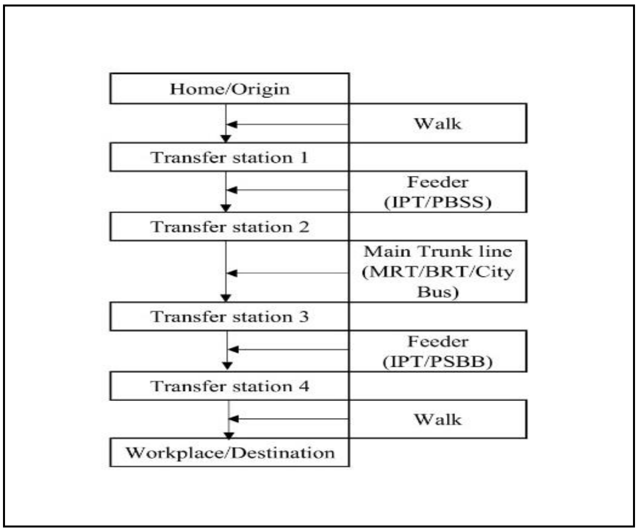

Figure 8 Unified arrangement of seamless travel

It can be perceived from the above flowchart in Fig. 8 that, PBSS system is to be implemented in two phases. The first phase is a part of the initial staging of the proposed feeder system with IPT as its sub-system purely on a pilot basis. This phase will cover the areas that are redundant to occupy Auto-rickshaw feeders. Further, in the second phase, PBSS shall cover the areas supplementary to IPT feeder and compete it to take over its ridership. Thus policy is to shift the urban travelers of the study area from automated to shared service and finally to non-motorized options.

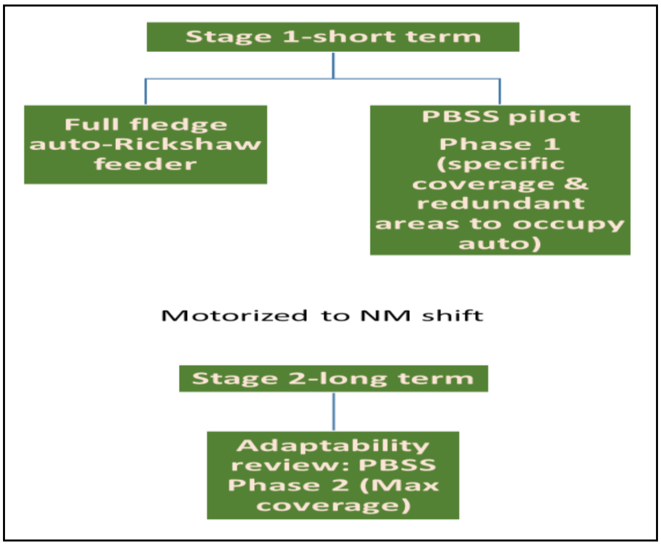

Figure 9 Phase wise planning of the feeder system

VI. PLANNING PRINCIPLES

As already discussed that program of public bicycle sharing system (PBSS) is planned on an ad-hoc basis, detailed proposals described hereon are divided into two segments, viz. Basic design strategy and phase-wise thorough planning. Planning of PBSS system considers various aspects noted as need assessment in terms of social, environmental, and political concerns; adaptability and affinity analysis; perception of users and ridership estimation; the spatial arrangement of the system, costing and budgets, etc. Results of SP survey and travel demand projection have been covered earlier, whereas now the spatial arrangement of the PBSS system is focused on the detailed design. For the implementation of a PBS system of the NMT approach, special attention has to be paid to infrastructure and supply management. The important elements of an efficient PBS system induce following, Designing of the entire PBSS system for study area included spatial location-allocation of docking stations, the number of bicycles per station, and redistribution mechanism. The preparation of such a comprehensive plan needs an effective and strategic design concept that is discussed below in the first segment of the PBS system design.

- Bicycles
- Docking stations
- Street supply infrastructure
- Operational infrastructure
- Data management system
- Redistribution system
- Control center
- Maintenance center

VII. STATION ALLOCATION CRITERIA

The proposed PBSS program is initially planned as a supportive system to organized IPT feeder services to serve the main modes of travel. Thus, several factors are considered to design this system in a strategic way that will deliver optimum service to users. The design strategy of PBSS is aimed to model out all elements of the system involving strategy for locating docking stations. Docking stations are the lodges designed to carry bicycles and dock spaces to act as a control center of the whole system. Conventionally only population density distribution component is considered for spatial allocations of docking stations, whereas certain other criteria essential for the same include activity and employment centers distribution, willingness to use data from SP survey and orientation of main public transport system, and other IPT service to which it acts as a feeder. Prime motto of this system is to serve transit stations by mobilizing potential commuters from their origins and vice-a-versa to complete the model of the first mile and last-mile connectivity. Thus conforming to all the above considerations, a method of maximum coverage is used to find out optimum locations of docking stations. According to this method, major potential origins and destinations are captured from a desire line diagram of the OD pattern of the study area and grouped systematically based on the mutual spaces between them. Such grouping is carried out to provide the docking stations at convenient walking distances. Considering 385 m stated access distance, buffer zones of 70% percent of this distance, i.e. 270 m are marked to take into account the redundancy of internal street network as shown in Fig. 10.

These 270 m radial buffer zones earmark spatial coverage of the docking stations if placed at the centroid of such grouped origins and destinations and are termed as the hub and spoke model for location-allocation of PBSS docking stations as shown schematically in Fig. 10. Collectively such groupings are called hubs and the connecting links to the hubs are spokes of the model. Such locations can be shifted manually to the nearest roads intersections and road alignment if the centroid is impending away from the road site. In this way, docking station locations based on area coverage and travel pattern of the study area. The next level of placement criterion for docking stations is compatibility with activity centers, stops and stations of main mode public transport lines and major road junctions to allow smooth interchanges of commuters to transfer the mode at such locations. Thus all major junctions in the vicinity to activity centers are focused on the next level of station allocation. Post the fixation of docking station hubs, the spokes are identified that well suits the feasibility and compatibility of the street network infrastructure. The connecting links have fulfilled the infrastructural components of the PBS system to accommodate area requirements of docking stations sizing and path for bicycling, etc. Since the existing block-level road network does not complement to desirable requirements, compromise is taken sufficiency of infrastructural provisions. It is assumed that bicycles will ride on the existing supply system of infrastructure.

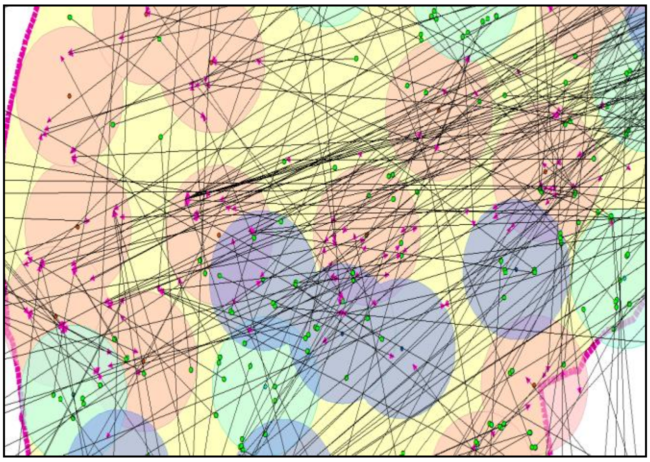

Figure 10 Maximum coverage approach of PBSS

Apart from the above-mentioned criterion, population density map of the study area along with land use mix data is outlined. The residential intensity of the total built-up area is trip generating focal points for first-mile connectivity while potential destinations of industrial and commercial intensities for last-mile connectivity. The locations not covered under the above criteria are thus covered by focusing on the intensified spatial distribution of land use and density. Generally higher densities of docking stations attract the commuters that allow shorter trips. There is no hard and fast rule, but the desired spacing between two docking stations i.e. spoke length is taken as 800 m out of thumb rule considering it as generalized preferred comfortable cycling distance.

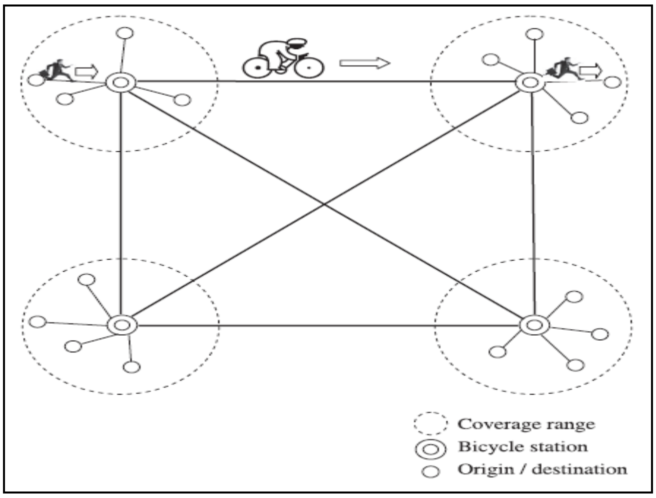

Figure 11 Hub and spoke model of PBSS

VIII. DOCKING STATION PLANNING

According to the origin-destination pair proposed docking station has been classified into 3 groups, namely large, medium & small docking stations. A large docking station defines as a junction where no. of trips are very high similarly Medium & Small docking station, where no. of trips moderate or less, respectively. The major junctions like Hirabaug BRTS, Lambe Hanuman Road BRTS, Baroda Prestige BRTS, Sarthana Nature Park BRTS, Kapodara, Vallabhacharya Road BRTS, Varachha Health Centre BRTS, etc. have been considered as Large Docking Stations with 30 bicycles at each station. The minor junctions like Lambe Hanuman Temple, Bombay Market, Yogi Chowk, Sitanagar BRTS, and Amazia Amusement Park BRTS, etc. have been considered as Medium Docking Stations with 20 bicycles at each station. After locating the Large and Medium Docking Stations with a buffer zone of 300 meters for each station, the gaps have been covered by locating the Small Docking Stations at optimum locations with 10 bicycles at each station. The docking station has been located at an average distance of 400-600 meters from each other to ensure mostly dense and uniform coverage in the high demand area.

The Docking Stations have also been located at the BRTS Stations to ensure no delay in the travel of the public. The Small Docking Stations have been located such that the people in the residential areas have easy accessibility and find minimum trouble in reaching the nearest docking stations. The Preliminary Identification has resulted in 63 Docking Stations out of which 7 are Large Docking Stations, 24 are Medium Docking Stations, and 32 are Small Docking Stations. The Large, Medium, and Small Docking Stations are proposed for the docking capacity of 30, 20, 10 bicycles respectively as shown in table 3, with 10% extra capacity at each docking station for redistribution.

Table 3 Number of the proposed Docking station in East Zone

Station	No. of a docking station	Bicycle per station	Total Bicycle
Large	7	30	210
Medium	24	20	480
Small	32	10	320
Total docking station	63	Total Bicycle without spare	1010
		Add extra 10% for Spare	101
		Total Bicycle	1111

Table 4 Classification of proposed Docking Stations

Type of PBS stations	*No. of stations*
Large stations	*7*
Medium stations	*24*
Small stations	*32*
Total	*63*

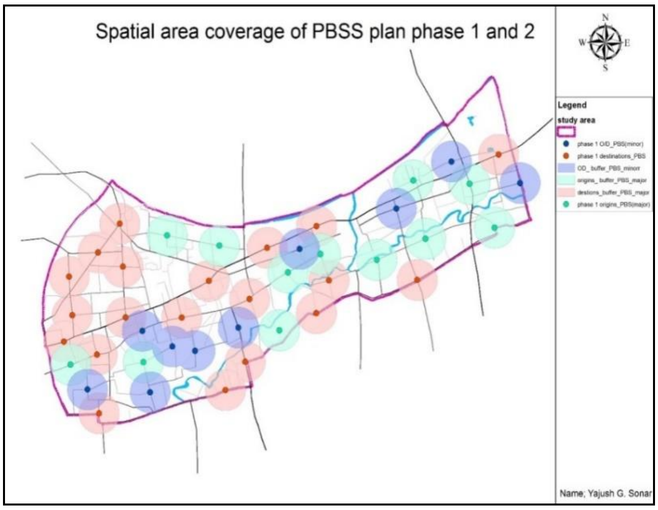

Figure 12 Phase 1 and 2 PBSS station with area coverage

IX. CARBON FOOTPRINT ANALYSIS

The word carbon footprint has seemed in the newscast often with the explosion of info that has appeared about environmental change. Carbon footprint shows the volume of greenhouse gas release, consisting primarily of CO2, connected with an event, production, or organization. This term measures the effect of a country or manufacturing on the climate. An increase in carbon footprint leads to an increase in global warming. It has many adverse effects on the Environment e.g. rising temperature and shifting precipitation pattern. PBS system will help to reduced greenhouse gas by shifting the public towards non-motorized transport. For every individual, company, or nation, there is a limit to which they can emit carbon dioxide in Air. This leads to the trading of carbon credit all over the globe

A carbon footprint is the total amount of greenhouse gas (GHG) emissions caused by society, event, product, or person. As we know that the increasing concentration of Green House Gases in the atmosphere can accelerate climate change and global warming, it is very necessary to measure these emissions. The first step to managing Green House Gas emissions is to measure them. There are some standards and guidelines to measure Green House Gas emissions like Greenhouse Gases' protocol, ISO 14064, Voluntary Carbon Standards (VCS), Life Cycle Assessment (LCA) and Clean Development Mechanism (CDM), etc. Out of them, ISO 14064 is an offset technique and independent, voluntary Green House Gas project accounting standard benefit to quantify Green House Gas emission of the society, event, product, or person (carbon footprint n. d.). All of the energy we use is derived from these fossil fuels, which are Green House Gas intensive.

The following assumptions have taken for the calculation of total fuel saved per annum.

- Considered only Petrol driven vehicles. I.e. Motorcycles
- Considering Avg. cost of fuel as INR 70.
- Avg. millage of the vehicle as 45kmpl (Kilometer per liter).
- Total working days are considered as 313 excluding no. of Sunday in a year

Table 5 Calculation of Total Trips in East Zone Surat

A.	*Total Trips*	*1038750*
B.	*Total trips by Car & Bike (54.90% of A)*	*570273.75*
C.	*Total trips of cars and bike with trip length less than 5 KM (36.60% of B)*	*208720.19*
D.	*Willing user trips (80.70% of C)*	*168437.19*
E.	*Peak Hour Demand (10% of D)*	*16843.71*
F.	*Satisfied people of Peak Hour Demand (70% of E)*	*11790.6*
G.	*Total trip length (Avg. trip length= 4KM)*	*4*11790.6*
		47162.41
H.	*Per km cost (Considering Avg. cost of fuel= INR 70, Avg. millage of vehicle= 45kmpl)*	*75/50=1.55 rupees per liter of fuel*
I.	*Total cost of Fuel (Per km cost=75/50= 1.55 rupees per litre of fuel)*	*47162*1.55 =73,101 INR*
J.	*Cost of fuel per year (Working days per year =365-52 =313 days)*	*313*73101*
		22880613
K.	*Total petrol/fuel saved per year*	*22880613/70*
		326865.9 liter

X. CONCLUSION

East zone has a scope for the adoption of a Public Bicycle Sharing System as a transportation mode for shorter trips based on the user's perception analysis. The proposed PBS system should also act as a feeder mode for the existing public transportation system to achieve the last mile connectivity. The survey is conducted for this study which helped to review public opinion about the use of the PBS system in East Zone. The first step was to define the scope of the work and objectives of the study. To meet the goals and objectives, several research articles, published in the reputed national and international journals, were studied to get the idea about the planning and designing of the Public Bicycle Sharing (PBS) System. To conduct the surveys, an online questionnaire survey was prepared in the Google Forms. 300 stated preference surveys were carried out in the Varachha (i.e. East Zone) to identify the details of users' travel patterns, socio-economic characteristics, willingness to use (WTU), and willingness to pay (WTP), etc. The data collected was analyzed on different parameters like travel distance, travel

Duration, the current mode of travel and many more to understand the willingness of the people to use the PBS System in MS–Excel. The major, minor junctions, and important locations were identified as potential Docking Stations for the PBSS system. The design criteria also include WTW distance and accordingly coverage area of the docking station is observed. After compiling all data, potential docking stations will be identified with the help of Arc GIS Software. The parameters like willing to walk and distance preferred on Bicycle etc. were of utmost importance for designing the PBS System. The result of the study proposed the implementation of 63 docking stations and 1111 cycles in the east zone. The mode shift scenario is calculated through observed data such as WTS, average trip length by car and bike. With the help of this, the probable saving of Carbon emission is calculated and the total carbon footprint comes out to 750.48 tons per annum by saving 3,26,865.9 liters of petrol per year.

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