How to determinate the trace of a cycling route in a district, based on demand and main attraction points

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***Abstract* — In the design of a cycling route, it´s important to do a prior planning process, considering demographic and social factors that allow to establish criteria in the election and theoutline of that route. With that, the cycling routes will providean adequate and safe route for cycling users. However, many ofthe existing routes in the city of Lima, Peru doesn't have anadequate planning system, which creates many problems for users when using during their travel trip. The objective of this research is to perform the planning process of a cycling route in the district of Jesus Maria, Lima. Using the latent demand model and travel demand estimation models based on the NCHRP and ITE. The document will propose travel routes that adjusts to the routes that users use in the district, according to the attraction points they are going to. The results of this study determined 595 possible travel routes in the district, which will be grouped into 6 final routes, connecting important areas for users, such as shopping centers, healthcare centers, recreational areas, etc.**

Keywords—:Cycling route; Demand Model; Cyclist User; Travel.

I. INTRODUCION

The National Cooperative Highway Research Program (NCHRP) investigates about existing problems in planning and design of roads. In general, the process to define a road involves some important factors, like the generation and distribution of trips, the choice of the mode and the travel demand. Also, previous reports confirm that the land use is very important to determine the travel demand. This research uses some information like employment, population and zonification data, which allows to know the amount of departure and arrivals of the people, based on the use they give. [1] However, some models may not be compatible with other realities outside North America. This occurs due to specific information required that can be difficult to obtain or doesn't exist in the proposed area.

Other researches, focused on cycling networks determine the travel demands based on preferences range. They establish that, depending on the user features, the zone, and the development level, they can be considered as cyclists or non-cyclists. [2]

Some researches carried out in the state of Idaho[3], show that deficiencies in the calculation of the volume of cycling travels can be modified if the origin-destination matrix is used. This allows to determine the most used routes, based on a gravitatory model. Other authors adds that another important factor to determine a cycling route is the registered traveled distance. [4] Maximum lengths are defined, establishing the probability that these will be made.

These studies agree that the factors to determine the demand and direction of the routes can be prioritized from others to obtain results when the information is not completed at all.

Considering the case of Lima city, the limited information and the lack of deepening about cycling networks, it is proposed to trace a cycling network in the district of Jesus Maria. The general travel demand is determined in the district, to then estimate the cycling travel demand, considering the most important factors. After wards, the origin-destination matrix methods are combined with the land uses, to trace the direction of the final route.

II. METHODOLOGY, INFORMATION AND CALCULATION METHODS

Fig.1 shows the network cycling trace process in the Jesus Maria District. First, required information was obtained to determine the travel demands in the district using the Mixed-Use Trip Generation Model [1]. Second, we proceeded to analyze and process the information according to the characteristics that the models required. Then, the cycling travel demands were estimated, using the Cycling Demand Model, having the results of the previous calculations in the first model as a base (total of travel demands) [6]. Next, the attraction points in the district were determined using the Latent Demand Method [5], to then determined all the possible travel routes in the district, and according to the demand, assign the importance of each route. Finally, the final routes were traced, considering the location and the direction of the possible routes, in addition to the routes election criteria, contributing to the right choice of these according to the traffic conditions, infrastructure and road continuity.

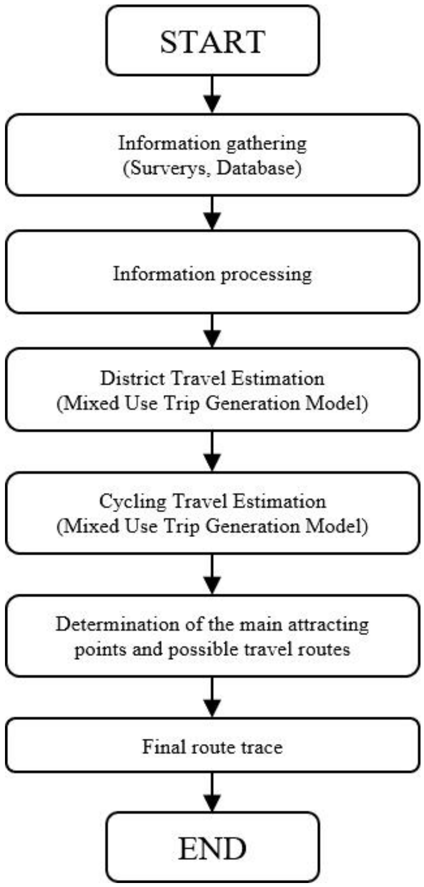

Fig.1. Flowchart of final route tracing process for cyclists.

A. *Tools*

An Excel spreadsheet, according to the described model,was used to calculate the travel demand in the district. It was developed by Ferh & Peers company.

B. *Information Compilation*

Information compilations were obtained through the data base from the inspection area of the Jesus Maria District, which consist of important information regarding to the number of existing jobs, area so fall existing companies in the district, number of houses, etc. On the other hand, a general survey was realized to obtain some information about the most frequent points of origin and destination that users usually made during their trips. The obtained information is summarized in Table I.

Information processing for the travel demand model in the district

To obtain the input information that Mixed used trip generation model requires, it was necessary to independently process each variable with additional information from the area due to the fact the model follows international standards, which aren't coupled in the same way in the study district. In addition, some employment index values were taken from the base model, due that this model allow us to use it in case of not being able to find any information in the studied area.

Table I.
Determined input variables for the model

Variable	Quantity	Unit	Average Rate Factor ITE
DwellingUnits			
Single Family	5,436	DU	9.57
Multi-family	15,396	DU	6.65
High Rise Condo	2,914	DU	4.18
Retail			
General Retail	70.513	Mmc	42.94
Supermarket	34.159	Mmc	102.24
Bank	7.672	Mmc	148.15
Health Club	27.567	Mmc	32.93
Restaurants	29.915	Mmc	127.15
Fast-Food	3.731	Mmc	496.12
Gas Station	5.362	Mmc	1181.07
Auto Repair	0.644	Mmc	31.6
Office			
Non-Medical	187.663	Mmc	11.01
Medical	201.351	Mmc	36.13
Industrial			
Light Industrial	2.664	Mmc	6.97
Warehousing/ Self Storage	2.099	Mmc	2.5
School			
University	74,627	Students	2.38
High School	8,560	Students	1.71
Middle School	6,340	Students	1.62
Elementary	16,802	Students	1.29
Others			
MovieTheater	8	Screens	5.63
Hotel	1,000	Rooms	175.29
DU = Dwelling Units Mmc =Thousand Square Meters			

C. *Travel Demand Estimation*

The calculation of travel demand will be determined by travel equation methods used in the Fehr & Peers spreadsheet: *Linear equations (1)*, *Logarithmic Equations (2)*, and *Average Ratio Equations (3)*. Each variable uses a different equation to obtain a value greater than or equal to zero.

$$Linear\ equations = x * lm + lc \quad (1)$$

$$Log.equations = e^{ln(x)*lm*lc} \quad (2)$$

$$Average\ ratio\ equations = x * AR \quad (3)$$

Where:
x: Input data value
lm: Multiplier Logarithm Parameter
lc: Constant Logarithm Parameter
AR: Daily Average Ratio of Input variable

The Multiplied Logarithm and Constant Logarithm parameters are defined by the Institute of Transportation Engineers (ITE) in equations (1) and (2). Those are based on trip generation manuals for road infrastructure design in the United States.

Table II.
Input variables for the model

Variable	Average Ratio Factor ITE	Multiplier Log.	Constant Log.
DwellingUnits			
Single Family	9.57	0.92	2.71
Multi-family	6.65	-	-
High Rise Condo	4.18	-	-
Retail			
General Retail	42.94	0.65	5.83
Supermarket	102.24	-	-
Bank	148.15	-	-
Health Club	32.93	-	
Restaurants	127.15	-	-
Fast-Food	496.12	-	-
Gas Station	1181.07	-	-
Auto Repair	31.60	-	-
Office			
Non-Medical	11.01	-	-
Medical	36.13	0.77	3.65
Industrial			
Light Industrial	6.97	-	-
Warehousing/ Self Storage	2.50	-	-
School			
University	2.38	-	-
High School	1.71	-	-
Middle School	1.62	-	-
Elementary	1.29	-	-
Others			
Movie Theater	5.63	-	-
Hotel	175.29	-	-

D. Cycling demand estimation

The cycling demand will be determined through population characteristics. A study made in wellington, revealed many characteristics of preference in the cyclist users, and were classified in six groups.

In this groups, the percentages of travel preferences were determined depending if these were made by private vehicle, public transport, walking, or in a bicycle.

TableIII.

Type of Cyclist According to the Wellington Model

Not cyclists	0.24%
Safe cyclists	0.33%
Likely cyclists	0.12%
Dedicated cyclists	0.05%
Recreational cyclists	0.17%
Indecisive cyclists	0.09%

Fig. 2 shows three different studied realities which were compared, according to the user characteristics. It is established that, if the age characteristics are similar in two populations, the travel preferences will have similar values.

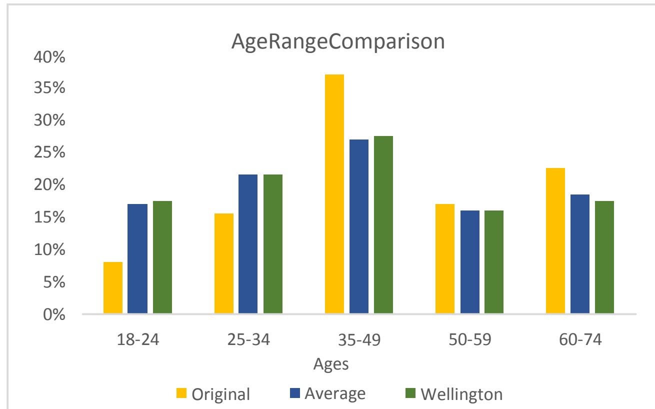

Fig.2. Segmentation of age ranges of three studies cases

The Wellington model and Jesus Maria district situation were compared. An average age range was found of the three proposals, and this information was the comparison about the two cases (Table IV). Population age data was taken and limited by the average age of death.

Table IV. Ages ranges comparison of the Wellington model and Jesus Maria district situation

Wellington Model		Jesus Maria		
Ages	%	Ages	Population	%
18-24	14.17	18-24	7 594	13.56%
25-34	19.5	25-34	11 593	20.71%
35-49	30.5	35-49	16 858	30.11%
50-59	16.33	50-59	9 160	16.36%
60-74	19.5	60-74	10 783	19.26%

Validating that this model applies due to the few variations it has according to the age range, it allows to determine then, the percentages of types of cyclists (Table III) and the values that correspond to the travel preferences according to each group. To calculate the demand for cyclists we have:

$$DTC = Tc \times Pv \times Dt \qquad (4)$$

Where:
DTC: Cyclist Travel demand

Tc: Percentage of cyclist type
Pv: Percentage of Travel reference
Dt: Total Travel Demands

E. *Attractor Points Definition*

The methodology known as Latent Demand Method [5] is based on land use. This means that, depending on the use given to a space, type of company or similar, the attraction of trips that it generates can be determined.

This influence factor is expressed as distance in miles that travel traffic influences and can be classified into 5 principal types of attractive points: *Workplaces, Universities, Schools, Shopping areas,* and *Parks*. About the influence factor of the parks, the study specifies

that only parks where planned recreational activities take place should be considered. (These parks should not be considered as transition parks).

The model and the current situation were compared. it was considered that the presence of the parks in the place of study fulfill more important recreational functions, so their influence factor doesn't adjust to this reality. Based on this, it was considered to take only some parks and consider the leisure areas.

The attractor points were determined according to *Offices, Universities and Institutes, Schools,* and *Commercial Zones*, based on the classification indicated by the methodology and the district zoning map. According to thedata currently registered in the Municipality of Jesus Maria and a cadastre, the main attracting points (legally considered) were located.

F. *Determination of possible routes*

Some investigations use the origin-destination method to determine the most used routes. This consists of having starting points of a trip, to then be connected jointly to a destination without any of them directing or repeating themselves. The following equation was used to calculate the number of possible routes (combinations) based on the number of attractor points:

$$C_m^n = \frac{n!}{n!\,(m-n)!} \qquad (5)$$

Where:
m: Number of attractor points
n: Number of possible combinations

G. *Route importance designation*

With the possible combinations for the obtained routes, their importance is assigned by calculating a K factor, using the following equation:

$$d = \frac{(x_2-x_1)2-(y_2-y_1)2}{2} \qquad (6)$$

$$k = \frac{(A_1-F_{i1})2-(A_2-F_{i2})2}{d^2} \qquad (7)$$

Where:
d: Distance between attractor points
X_1: X coordinate of the origin point
X_2: X coordinate of the destination point
Y_1: Y coordinate of the origin point
Y_2: Y coordinate of the destination point
k: Route importance factor
A_1: Origin point area
A_2: Destination point area
Fi_1: Influence factor for land use of the origin point
Fi_2: Influence factor for land use of the destination point

To determine the main routes, the travel demand mustthen be calculated for each of the routes found. For this, the value of k is replaced, it is multiplied by the constant that accompanies it, and all the routes are added, and equalized with the total demand for trips.

$$DTC=\sum(ka) \qquad (8)$$

Where:
DTC: Total demand for cycling trips
k: Route importance factor
a: Constant

Once the value of the additional constant is determined, it is multiplied by each corresponding *k*, to determine the demand for cycling trips for each route.

$$DCR = ka \qquad (9)$$

Where:
DCR: Cycling demand trips by route
k: Route importance factor
a: Constant

Based on the values obtained, the main routes are designated, the directions they must follow, and the main points of attraction that must connect to satisfy most of the demand.

H. *Trace of possible routes*

The importance of the routes is counted, and they are ordered from highest to lowest, with the purpose of determining which are the main ones. According to the Pareto principle, the 20% of the less important routes have such low values that they don't influence the main 80%. From this, the main routes were grouped according to the ranges of demand that the results produced. Once 80% of the demand is covered, an additional 10% of the routes are drawn to clarify which are the points of greatest influx.

Captured 90% of the trips, three criteria are followed to choose the specific streets where the bike lane will be: ***the continuity criteria, the low traffic density, and the dimensions of the streets.***

III. RESULTS

A. Travel demand

With the application of the Mixed-Use Trip Generation Model, the number of trips that each sector demands were determined. The number of daily trips obtained was 683,118.

The education sector is one of the most influential in the travel demand in the district (214,139), due to the number of university students within the sector (177,612) is the one that contribute, almost 25% of the total demanded trips in the district.

Another important sector that contributes with great demand is the Retail sector (214,139) because it comprises many variables that have a greater area in cubic feet, compared to the others.

Fig.3 shows the number of trips generated according to each sector in the district. It is inferred that, the sectors with the highest number of trips are those with the most important points of attraction for the population of Jesus Maria.

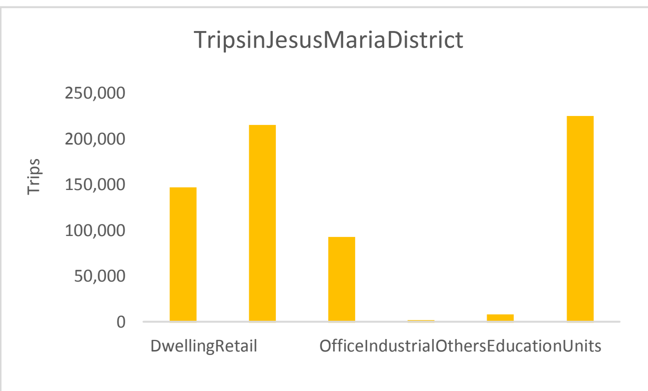

Fig.3. Total Trips in Jesus Maria by sector

B. Cycling Travel Demand

181,026 trips made by bicycle were obtained in the district of Jesus Maria applying equation (4). Table V, shows the number of cycling trips and the percentage respect to the total demand, according to the type of cyclist estimated by the model.

It is implied that, under the parameters of the model, about 62.26% of the estimated bicycle trips in the district will be made by users who have a constant use of bicycle.

Cycling Travel Demand		
Cyclist type	Number of travels	%
Not cyclists	0	0.00 %
Safe cyclists	112,714	62.26 %
Likely cyclists	25,412	14.04 %
Dedicated cyclists	13,662	7.55 %
Recreational cyclists	25,549	14.11%
Indecisive cyclists	3,689	2.04%

C. Attractor Points

Using the Latent Demand Method and district zoning, the main attractors were identified, based on the 4 main classifications. Making a visual analysis, a total of 35 attractor points were considered.

Fig.4 shows some of these points, formed of higher education centers (for instance, Peruvian University of Applied Sciences), schools (for instance, Teresa Gonzales de Fanning), commercial areas (for instance, Real Plaza located in Av. Salaverry) and work points (for instance, Hospital Edgardo Rebagliati Martins).

Fig.4. Principal attractor points in the district

D. Determination and designation of possible routes

Using equation (5) and considering the number of main attractor points, 595 possible travel routes in the district were determined.

Fig.5 shows the Pareto graph, which determines that 58 of the possible routes are part of 80% of these. Moreover, an additional 10% is being considered due to some of the selected routes, have bicycle routes already built. The total number of possible routes is 106.

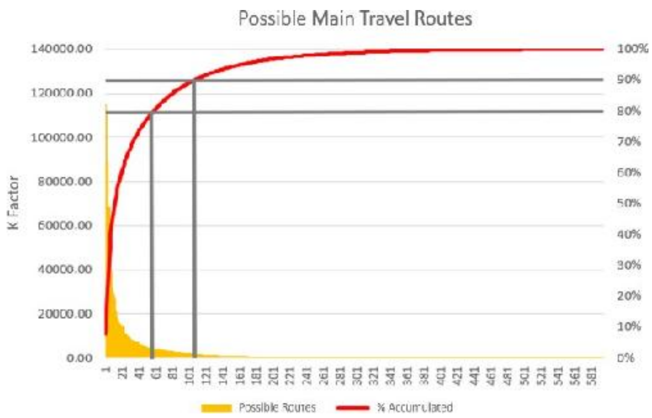

Fig.5. Principal Attractor points in the district

E. Route Trace

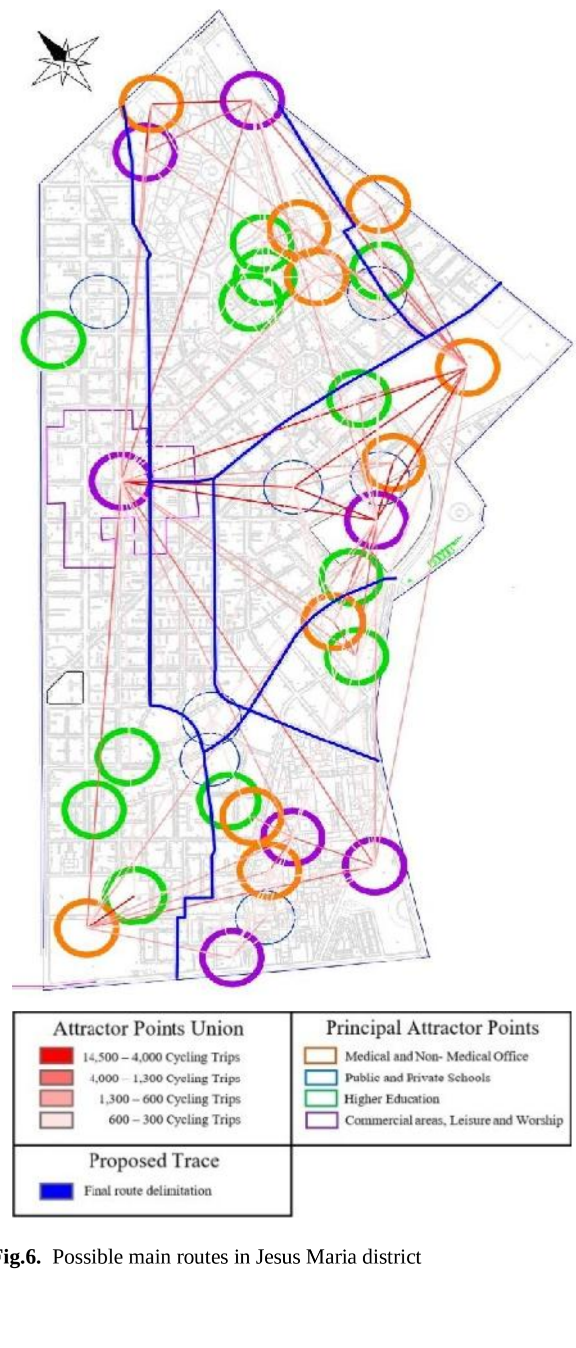

Fig.6. Possible main routes in Jesus Maria district

With the amount of possible important routes found, the final routes in the district are traced, considering the important points of attraction that these possible routes have in common. Fig. 6 shows the layout of the final routes in the district. As seen, the blue lines correspond to the final routes for cyclists, from North to South and from East to West. The circles, according to their color, correspond to important points of attraction in the district: orange (offices), light blue (schools), green (higher education institutions) and purple (shopping areas). Each route was traced based on the continuity criteria, the low traffic density, and the dimensions of the streets, which allowed choosing the direction of the routes avoiding problems of traffic, space, and interruption of continuity of these.

IV.CONCLUSIONS

By using the approach of the demand estimation methodologies in the study area, it can be estimated that at least 25% of the general trip's demands can be supplied through the proposed bike path route. The contrast of the populations between the district of Jesus Maria and the city of Wellington allowed us to confirm that the socio demographic behavior is similar, in terms of percentages. The percentage difference between each age range is ±0.5%. To assign importance to each of the routes, areas, coordinates, and importance factors of each attractor point were used. Therefore, the number of cycling trips for each of these was obtained, which were grouped and allowed to identify the most important within the district. According to the criteria of continuity in the layout of the routes, those that demanded a greater proportion of cycling trips were considered. The monitoring and direction of the routes selected avenues and streets with fluid traffic and adequate lane width. The most important routes join the district, in the central zone in an East-West direction, and along, from Southwest-Northwest.

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