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PREFERENCE ASSESSMENT OF CYCLISTS, PEDESTRIAN AND MOTORISTS ABOUT THE INTEGRATION OF CYCLE TRACKS AND PEDESTRIAN PATHS AT ROUNDABOUTS

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Abstract: In this study, three roundabouts were selected in Chandigarh , India. The aim of the work is the preference assessment of cyclists, pedestrians and motorists about the integration of cycle tracks and pedestrian paths at roundabouts at the three selected sites with different pedestrian and cyclist infrastructure. A questionnaire survey was prepared and responses to this questionnaire survey were collected manually from the three selected sites. A total of 251 responses were taken manually for this assessment in which 49% were male and 51% were female. Out of the 251 responses collected it has been seen that 36.7% of them are pedestrians, 29.9 % are cyclists and 33.4% (88) are motorists. The analysis was done on SPSS(Statistical Package for the Social Sciences) using the k-means clustering algorithm. In this study 3 clusters were formed for the pedestrian/cyclist group and motorist group using k-means clustering algorithm. In case of the pedestrian and cyclists the formation of the three clusters was mainly dominated by travel time with a F value as 59.6 .The other parameters which dominate the clustering of groups were awareness, abidance of dedicated tracks and convenience with F values as 49.2, 41.8 and 38.5 respectively. From cluster 3 that has the maximum number of members it can be concluded that most of the females are aware about the use of cycle tracks and pedestrian paths and they tend to follow them always. Also, most of the females prefer a separate track for the cyclists and pedestrians over a combined track for both. In case of the motorist the factor which is most effective in the formation of clusters is trip delay with F value- 221.6 Most of the motorists mainly comprising of the young and elderly age group feel that their speed is impacted and trip delays are caused due to presence of separate pedestrian paths and cycle tracks. Most of the people of moderate age group are aware about the use of cycle tracks and pedestrian paths and most of them prefer integrated roundabout concept over foot over bridges.

KEYWORDS–Cycle tracks, Pedestrian paths, Roundabouts, Preference assessment, Travel time, k-means clustering.

INTRODUCTION

A roundabout is a traffic juncture where all heterogeneous vehicles must drive in one way around a central island before migrating out of traffic flow into their multiple directions radiating from the central island. In India, the movement around the island is done in a clockwise orientation, similar to how we follow the rule of 'stay to the left.' The main aim is to minimize the area of conflict by eliminating the need to halt even when crossing streams of vehicles. The number of conflict points is lowered from 32 for a cross intersection to 8 for a roundabout, removing all crossing conflict points completely. Roundabouts maintain traffic flow by lowering vehicle speeds.

Cycling and walking are important modes of transportation that are sometimes neglected in the age of high-tech motorised travel. As a result, they are a topic of great interest to the transportation research community. While roundabouts tend to be safer for motorised cars, the evidence for a similar safety effect for walkers and cyclists is mixed. The government is constructing integrated cycle tracks and pedestrian paths to guarantee the safety of

pedestrians and cyclists.

Chandigarh, it is the first planned city of India and roundabouts are the beauty of Chandigarh city. As a result of Chandigarh's development of cycle-friendly roundabouts, the integration of cycle tracks and pedestrians at roundabouts has become a highly debated issue, capturing everyone's attention. The administration of Chandigarh has built the city's first cycle-friendly roundabout in Sector 26. This 1.5-kilometer cycle track runs from the Sector 26 Grain Market roundabout to the Sector 26 Transport Light Point. The cycle track has been placed on the same level as the road, and a separate pedestrian pathway has been provided in these roundabouts. To distinguish them, different colours such as red and grey were used. When crossing a roundabout, a bicycle must ride on the red-colored path, and no other vehicle is permitted to drive into the red-colored paver stones. These roundabouts with integrated pedestrian crossings and cycle tracks are intended to promote bicycle and pedestrian activity. The majority of roundabouts in Chandigarh have been converted pedestrian and bicycle friendly. Some have a combined cycling and pedestrian lanes, while others have separate cycle and pedestrian paths.

Figure-1 Roundabout with separate cycle track and pedestrian path
(source-google images)

Figure 2- Roundabout with combined cycle track & pedestrian crossing
(source-google images)

OBJECTIVE OF THE STUDY

The aim of this paper is the preference assessment of cyclists, pedestrians and motorists about the integration of cycle tracks and pedestrian paths at roundabouts at the three selected sites with different pedestrian and cyclist infrastructure. The objective wishes to analyse the choice of road user regarding pedestrian and cycle infrastructure.

LITERATURE REVIEW

Meijer Riske; Dam Esra van; Bouma Henri; Baan Jan; Hurk Sander E. van (2020) investigated the possibilities of assessing behaviour indicators that represent infrastructure's effects on other road users. Six cameras were placed above a divided cycle path close to a road, which contained a crossing with both cyclists and cars, for an observation study. The bikers were automatically detected using a learning system based on Single Shot Multi-Box Detector, and their tracks were determined. Using the measurement method proposed in this study, it is possible to evaluate cyclists'

intensity, the space they use on the bike lane, their average velocity, waiting times, the space and velocity between them, and red light wilful ignorance. **Matar Hamad B, Almutairi Talal, and Mutairi Nayef Z (2020)** conducted Al- a factor and cluster analysis of traffic pattern variance in a road network, taking into account daily human travel activities. They compared various Data Mining clustering approaches for grouping roads based on their traffic profiles in a study. Data from 45 Automatic Traffic Recorder (ATR) sites across the United Kingdom was used in the investigation. Five roads were divided into categories. **Rahul T.M. and Ashish Verma (2018)** established a framework for calculating the Composite Sustainability Index (CSI) to highlight the impact of establishing separate walkways and cycling lanes on sustainability. The study establishes a link between the Non-Motorized Transport (NMT) infrastructures and CSI using explanatory indicators. It entails computing explanatory indicators for conditions before and after the installation of NMT infrastructure, as well as establishing the infrastructure's long-term impact. The results of all case studies show an increase in CSI and a better long-term viability of building separate pathways and cycle lanes. Furthermore, from the angle of social equality, developing NMT infrastructure provided low-income residents with an alternative mode of transportation, reducing their dependency on public transportation. The full streets idea is outlined by **Al-Mosaind Musaad (2018)** as a street design that can securely accommodate all kinds of mobility for all members of the community. Other community goals, such as environmental protection, social integration, healthy lifestyle, entertainment, and economic progress, are also addressed. Streets serve as a hub for interaction and communication, transportation, social, and business transactions for the general public. Around the world, the concept of a "complete street" is gaining traction. The purpose of this study was to examine the current situation of several functional roadway classifications in a few Riyadh neighbourhoods to see if the complete streets ideology could be applied to streets both inside and outside of neighbourhood. **Aldred Rachel et al. (2016)** performed a comprehensive review of stated preference studies to see how much gender and age disparities in cycling infrastructure preferences exist. They found 54 studies that investigated whether gender and/or age differences in cycling infrastructure preferences existed. According to the studies, women reported a greater need for more separation from traffic than men. There were less signs of greater preferences among elderly people. There were quantitative rather than qualitative variations in preferences: certain groups valued separated infrastructure more than others, but no group preferred integration with motor traffic. According to **Gotschi Thomas et al. (2016),** the health benefits of daily riding have gotten attention from both the health and transportation and planning sectors, which are seeking for ways to justify cycling expenditures. Air pollution concerns are likely to be modest due to the lack of evidence supporting cycling-specific processes. Based on a substantial body of research, planners, health specialists, and decision-makers may rest assured that the advantages of cycling-related physical activity are desirable to pursue. Improvements in safety should be incorporated in attempts to encourage cycling, both to mitigate negative outcomes and to remove obstacles to potential riders. **Candappa Nimmi et al. (2014)** aimed to make roundabouts safer and more convenient for pedestrians. In terms of safety and convenience, crossing compliance and crossing duration were also analyzed. A questionnaire was employed to analyze pedestrian views of the roundabout's security and efficiency before and after treatment. According to the results of this case study, mean approach speeds (free speeds 30 metres from the crossing) dropped from 32.7 to 30.7 kilometers per hour, while mean speeds just before crossing dropped from 19.1 to 16.3 kilometers per hour. There was also a significant reduction in the number of cars travelling at speeds that endangered pedestrians. Total crossing time dropped by about 4 seconds after treatment, and crossing compliance increased from nearly half to over 90%. According to a poll, pedestrians rated the perceived convenience and security of the treatment as advantageous. Less exposure to traffic and a lower chance of serious injury, particularly for senior walkers, are safety implications; convenience results include shorter crossing times and more compliance with the crossing. **T.M. Rahul and Ashish Verma (2012**) separated their research into two parts. The first part of the report examines the evolution of non-motorized travel in India. The second section is divided into two case studies conducted in Bangalore, which were used to demonstrate the economic benefits. The first study establishes a framework for determining the economic benefits. Congestion, accidents, car expenditures, and reductions in air pollution are all taken into account, and total savings are determined. A savings of Rs.250,000 was discovered for an expected shift of 1% of users to non-motorized mode in a single day. The second study looks at the possible economic benefits of pedestrianizing M.G. Road in Bangalore, projecting a daily savings of Rs. 1611.4 due to lower air pollution and fewer accidents.

DATA COLLECTION

Firstly the site selection was done. Three roundabouts were selected with different pedestrian and cyclists infrastructure Chandigarh city in North India. First is the internal rotary of sector 11 near civil dispensary (roundabout with cycle track and pedestrian crossing). Second is roundabout at PGI Chawk, roundabout joining sector 11-12-14-15 (Roundabout with a combined pedestrian track and cycle track) and third is roundabout at Junction 18 Park near Government Multi speciality Hospital (Roundabout with separate pedestrian track and cycle track).

A questionnaire survey was prepared to do the preference assessment of the cyclists, pedestrians and motorists. The questionnaire survey was prepared in four parts. The first part is the demographic survey- Name, age , gender , mode of travel, vehicle ownership. The second part consist of trip details- Trip purpose and Trip time. The third part has questions to be asked by the pedestrian/ cyclists related to - convinience, awareness, abidance of the dedicated tracks, signalized or unsignalized for pedestrian and cyclists and the fourth part is for the motorists- convinience, impact on speed, trip delays and more.

Responses to this questionnaire survey were collected manually from the three selected sites. A total of 251 responses have been taken manually for this assessment in which 49% were male and 51% were female.

DATA ANALYSIS AND RESULTS

Out of the 251 responses collected it has been seen that 36.7% of them are pedestrians, 29.9 % are cyclists and 33.4% are motorists. The analysis of the collected data was done on SPSS(Statistical Package for the Social Sciences) using the K-MEANS CLUSTERING algorithm.

SPSS (Statistical Package for the Social Sciences) is a quantitative data analysis software application. It is a programme for performing statistical analyses. Qualitative data is information that describes the characteristics or qualities of something. Questionnaires, interviews, and observations are all used to collect information. It is difficult to analyze qualitative data. Researchers can use coding to organise qualitative data, uncover themes that relate to the research questions, and do quantitative analysis.

Unsupervised learning is what K-means clustering is. We use this strategy while dealing with unlabeled data, or data that lacks clearly defined classifications and categories. The goal of K-means clustering is to find groups in a collected data, with K denoting the number of groups. The centroids are calculated initially, then iterations are performed until the optimal centroid is identified using the K-means clustering algorithm. The number of clusters is presumptively known. The primary stages in K-means clustering are to determine the number of clusters K, then choose k random points from the provided data as centroids, and then assigning all the data points to the closest cluster centroid, and finally recompute the centroids of the newly established clusters, and repeat.

Table 1.Conversion of Options to Numeric Values for Statistical Analysis

Parameters	Options	Numeric representation of Options
Gender	Male	1
	Female	2
Mode of Travel	Motorist	11
	Cyclist	12
	Pedestrian	13
Trip Purpose	Work	6
	Education	7
	Recreational Activity	8
	Fitness	9
	Social Activity	10
Convenience	Yes	101
	No	102
	Neutral	103
Lane Choice	Combined	104
	Separate	105
Awareness	Yes	201
	No	202
Following	Always	203
	Never	204
	Sometimes	205
Signalized or Not	With Signal	207
	Without Signal	208
Likeliness	Yes	301
	No	301.1
	Not Sure	301.2
All Integrated or Not	Yes	401
	No	401.1
	Not Sure	401.2
Impact on Speed	Yes	501
	No	501.1
Trip Delay	Yes	601
	No	601.1
Integrated v/s FOB	Yes	701
	No	701.1

FOR PEDESTRIAN AND CYCLIST
Three clusters are formed through k-means clustering algorithm.

Table 2- Descriptive Statistics for pedestrian and cyclists

	N (number of responses)	Minimum Value	Maximum Value	Mean Value	Std. Deviation
AGE	163	14	68	31.54	11.619
GENDER	163	1	2	1.58	.495
MODE OF TRAVEL	163	12	13	12.54	.500
TRIP PURPOSE	163	6	10	7.35	1.312
TRAVEL TIME	163	5	90	24.23	18.820
CONVENIENCE	163	101	103	101.61	.871
LANE CHOICE	163	104	105	104.74	.439
AWARENESS	163	201	202	201.17	.378
FOLLOWING	163	203	205	203.82	.929
SIGNALIZED OR NOT	163	207	208	207.66	.474
Valid N (listwise)	163				

Table 3-Final Cluster Centers for pedestrian and cyclists

	Cluster		
	1	2	3
Zscore(AGE)	.59814	-.39074	-.22523
Zscore(GENDER)	-.74817	.33800	.29912
Zscore: MODE OF TRAVEL	-.73941	.25361	.30490
Zscore: TRIP PURPOSE	-.42854	-.20294	.21708
Zscore: TRAVEL TIME	-.08361	2.29898	-.22748
Zscore(CONVENIENCE)	.89059	-.50602	-.34409
Zscore: LANE CHOICE	-.72213	.20744	.30241
Zscore(AWARENESS)	.95186	-.01351	-.42861
Zscore(FOLLOWING)	.78690	.72965	-.43981
Zscore: SIGNALIZED OR NOT	-.90353	.53573	.34651

NOTE: “z-score” is the standardized value for a set of variables. The absolute value of z represents the distance between the raw score x and the population mean in units of the standard deviation. Z-score is negative when the raw score is below the mean and positive when it is above the mean. The purpose of standardizing data to z-score is to compare sets of variable of different units. If the population mean and standard deviation is known the z-score can be calculated by $Z = \frac{x-\mu}{\sigma}$, where μ is mean and σ is standard deviation (The mean μ and σ for parameters taken into consideration are tabulated in table 1)

Table 4- Interpretation on the basis of final cluster centres based on table 2 for pedestrian and cyclists

PARAMETERS	CLUSTER 1(47)	CLUSTER 2(12)	CLUSTER 3(104)
AGE	ELDERLY	YOUNG	MODERATE
GENDER	MALE dominant	FEMALE dominant	FEMALE dominant
MODE OF TRAVEL	CYCLIST	BOTH	PEDESTRIAN
TRIP PURPOSE	WORK dominant	EDUCATION dominant	RECREATIONAL ACTIVITY, SOCIAL ACTIVITY, FITNESS dominant
TRAVEL TIME	10-30 MIN	MORE THAN 30MIN	0-10 MIN
CONVINIENCE	NEUTRAL dominant	NO dominant	YES dominant
LANE CHOICE	COMBINEDdominant	BOTH	SEPARATE dominant
AWARENESS	NO dominant	BOTH	YES dominant
FOLLOWING	SOMETIMES	NEVER	ALWAYS
SIGNALIZING	WITH SIGNAL dominant	WITHOUT SIGNAL dominant	BOTH

Table 5- Distances between Final Cluster Centers for pedestrian and cyclists

Cluster	1	2	3
1		3.833 units	3.294 units
2	3.833 units		2.864 units
3	3.294 units	2.864 units	

NOTE- The distances represented in the above table are Euclidean distances. They represent the distances between the final cluster centres. Larger the distance between clusters, greater is the dissimilarity between clusters.

Table 6-Anova table for pedestrian and cyclist

	Cluster		Error			
	Mean Square	df1	Mean Square	df2	F	Sig.
Zscore(AGE)	11.961	2	.863	160	13.861	.000
Zscore(GENDER)	18.492	2	.781	160	23.667	.000
Zscore: MODE OF TRAVEL	18.068	2	.787	160	22.968	.000
Zscore: TRIP PURPOSE	7.013	2	.925	160	7.583	.001
Zscore: TRAVEL TIME	34.567	2	.580	160	59.556	.000
Zscore(CONVENIENCE)	26.332	2	.683	160	38.534	.000
Zscore: LANE CHOICE	17.269	2	.797	160	21.677	.000
Zscore(AWARENESS)	30.845	2	.627	160	49.201	.000
Zscore(FOLLOWING)	27.804	2	.665	160	41.815	.000
Zscore: SIGNALIZED OR NOT	27.150	2	.673	160	40.335	.000

NOTE- 1. df1(degree of freedom associated with mean)= number of clusters-1
2. df2(degree of freedom associated with random errors)= number of total observation – df1-1
3. Mean square(MSt) is the relevant sum of squares divided by its degree of freedom.
4. The mean square for within groups is often called Mean Square Error (MSe)
5. The F-ratio is MSt/MSe. Greater the value of F the more is the contribution of a particular characterstic in the formation of clusters.
6. If the value of Sig. is less than 0.05 the characterstic have significance in differentiating the group.

Table 7-Number of Cases in each Cluster for pedestrian and cyclists

Cluster	1	47
	2	12
	3	104
Valid		163

NOTE- Out of 251 responses these clusters are for pedestrians and cyclists that are 163 in total.

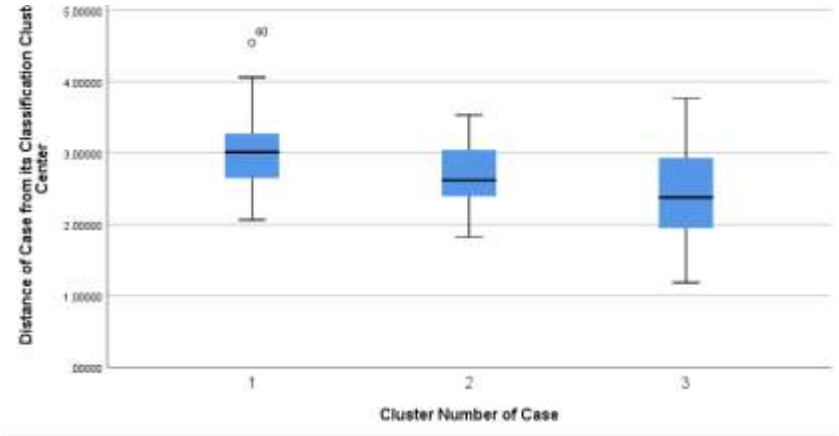

FIGURE 3- Simple boxplot of distance of case from its classification Cluster center by cluster number of case for pedestrian and cyclist.

NOTE- The y-axis represents Euclidean distances in coordinate system and hence has no units.

FOR MOTORIST

Three clusters for motorists are formed based on k-means clustering.

Table 8-Descriptive Statistics for motorist

	N (number of responses	Minimum Value	Maximum Value	Mean Vaue	Std. Deviation
AGE	88	18	56	31.12	7.656
GENDER	88	1	2	1.36	.484
MODE OF TRAVEL	88	11	11	11.00	.000
TRIP PURPOSE	88	6	10	6.70	1.063
TRAVEL TIME	88	0	90	42.90	27.738
LIKELINESS	88	301.0	301.2	301.098	.0816
ALL INTGD OR NOT	88	401.0	401.2	401.105	.0605
IMPACT ON SPEED	88	501.0	501.1	501.027	.0448
TRIP DELAY	88	601.0	601.1	601.027	.0448
INTGTD vs FOOT OVER BRIDGES/SUBWAYS	88	701.0	701.1	701.078	.0414

Table 9-Final Cluster Centers for motorist

	Cluster		
	1	2	3
Zscore(AGE)	-.62586	.68028	-.43785
Zscore(GENDER)	.16703	-.38063	.46976
Zscore: TRIP PURPOSE	.87021	-.59039	-.02138
Zscore: TRAVEL TIME	-.49837	.67204	-.57970
Zscore(LIKELINESS)	-.28980	.49909	-.52907
Zscore: ALL INTGD OR NOT	.10857	.34883	-.75162
Zscore: IMPACT ON SPEED	-.36082	-.26541	.91332
Zscore: TRIP DELAY	-.60888	-.43715	1.62369
Zscore: INTGTD vs FOOT OVER BRIDGES/SUBWAYS	.34275	.33587	-1.01606

Table 10- Interpretation based on final cluster centres for motorist

PARAMETERS	**CLUSTER 1(27)**	**CLUSTER 2(39)**	**CLUSTER 3(22)**
AGE	YOUNG	ELDERLY	MODERATE
GENDER	BOTH dominant	FEMALE dominant	MALE dominant
TRIP PURPOSE	SOCIAL ACTIVITY, FITNESS dominant	WORK AND EDUCATION dominant	RECREATIONAL ACTIVITY, EDUCATION dominant
TRAVEL TIME	10-30 MIN	MORE THAN 30 MIN	0-10 MIN
CONVINIENCE	NO dominant	NOT SURE dominant	YES dominant
ALL INTEGRATED OR NOT	BOTH dominant	NO dominant	YES dominant
IMPACT ON SPEED	YES dominant	YES dominant	NO dominant
TRIP DELAYS	YES dominant	YES dominant	NO dominant
INTEGRATED / FOOT OVER BRIDGE	FOOT OVER BRIDGE dominant	FOOT OVER BRIDGE dominant	INTEGRATED dominant

Table 11-Distances between Final Cluster Centers for motorist

Cluster	1	2	3
1		2.496 units	3.191 units
2	2.496 units		3.687 units
3	3.191 units	3.687 units	

NOTE- The distances represented in the above table are Euclidean distances. They represent the distances between the final cluster centres. Larger the distance between clusters, greater is the dissimilarity between clusters.

Table 12- Anova table for motorist

	Cluster		Error			
	Mean Square	Df1	Mean Square	Df2	F	Sig.
Zscore(AGE)	16.421	2	.637	85	25.773	.000
Zscore(GENDER)	5.629	2	.891	85	6.317	.003
Zscore: TRIP PURPOSE	17.025	2	.623	85	27.330	.000
Zscore: TRAVEL TIME	15.856	2	.650	85	24.378	.000
Zscore(LIKELINESS)	9.070	2	.810	85	11.196	.000
Zscore: ALL INTGD OR NOT	8.746	2	.818	85	10.696	.000
Zscore: IMPACT ON SPEED	12.307	2	.734	85	16.768	.000
Zscore: TRIP DELAY	36.411	2	.164	84	221.586	.000
Zscore: INTGTD vs FOOT OVER BRIDGES/SUBWAYS	15.142	2	.667	85	22.693	.000

Table 13- Number of Cases in each Cluster for motorist

Cluster	1	27
	2	39
	3	22
Valid		88

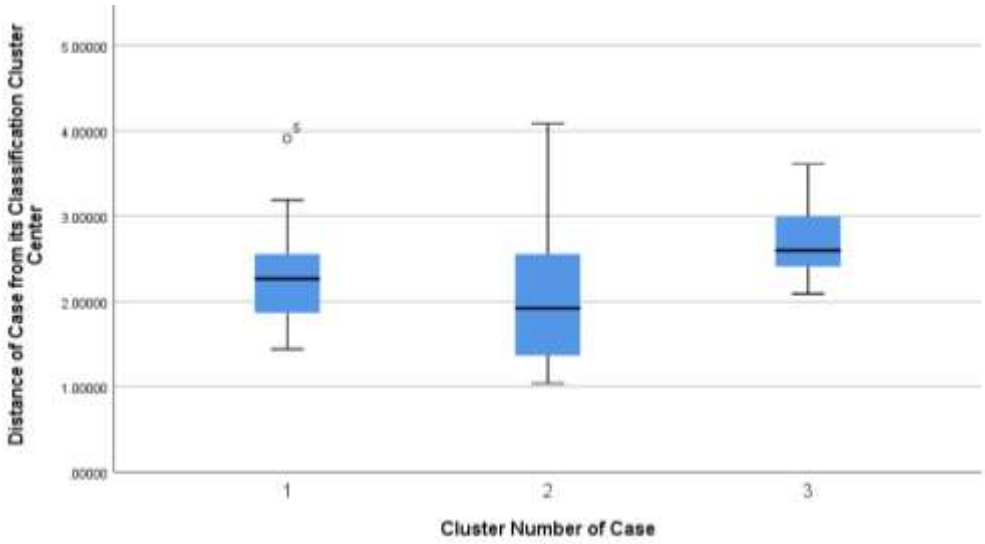

FIGURE 4- Simple boxplot of distance of case from its classification Cluster center by cluster number of case for motorist

NOTE- The y-axis represents Euclidean distances in coordinate system and hence has no units

CONCLUSIONS

In this paper k-means clustering algorithm has been used to form 3 clusters each for the pedestrian/cyclist group and motorist group.

For pedestrian and cyclist it can be concluded that-

1. The formation of the three clusters are mainly dominated by trip travel time with a F value as 59.6 .The travel time corresponding to cluster 1 and cluster 3 is 10-30 min and 0-10 min respectively.
2. The other parameters which dominate the clustering of groups are awareness, abidance of dedicated tracks and convenience with F values as 49.2, 41.8 and 38.5 respectively.
3. From cluster 3 that has the maximum number of members i.e. 104 we can conclude that most of the females are aware about the use of cycle tracks and pedestrian paths and they tend to follow them always. Also, most of the females prefer a separate track for the cyclists and pedestrians over a combined track for both.
4. Cluster 1 has 47 members and majority of them are elderly. Thus we can conclude that most of the elderly age group is unaware about the use of cycle tracks and tend to use it sometimes.
5. The F-stat is 7.6 for Trip purpose which indicates that it is least effective factor for cluster formation.

For motorist it can be concluded that-

1. The factor which is most effective in the formation of clusters is trip delay with F value 221.6 .
2. Most of the motorists mainly comprising of the young and elderly age group feel that their speed is impacted and trip delays are caused due to the presence of separate pedestrian paths and cycle tracks. They prefer foot over bridges over integrated cycle and pedestrian infrastructure at roundabouts.
3. The factor which is least effective in formation of these clusters is Gender with a F value 6.3

On comparing cluster 3 for the cyclists/pedestrians and cluster 3 for the motorists we can conclude that most of the people of the moderate age group are aware about the use of cycle tracks and pedestrian paths which they follow always and most of them prefer integrated roundabout concept over foot over bridges.

RECOMMENDATIONS

1. More number of responses can be taken based on the population study so that a thorough investigation can be done more precisely and errors may reduce due to the increase in the sample size.
2. The people of elderly age group should be made aware about the use of pedestrian paths and cycle tracks.
3. Sign boards should be placed near the pedestrian paths, cycle track in the local languages or any language which is easy to understand for the local people. These sign boards should be placed without making any hinderance to the cycle path or pedestrian tracks.
4. There should not be any hinderances like light poles , road signs, trees etc in between the movement for the pedestrian and cyclists on these tracks because of which people tend to change their paths.
5. Proper lighting should be provided on the pedestrian paths and cycle tracks to encourage people to use it .

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