Analysis of Elderly Road User's Characteristics at Roundabout: A Case Study

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***Abstract*—At present, the design of urban road intersections considers only conventional road user's characteristics. As the population of elderly road users comprises about 8.2% of the total population, i.e. aged 60 years or above. As the elderly commuters population increases, their incompatible characteristics also play an important role in the road geometry performance analysis. The elderly road user's characteristics did not consider during the planning and designing of the roundabout. Consequently 90% elderly road users involved in major or minor accident at intersection. In this study, revealed preference survey experiments and videography survey was conducted at roundabout for three days, and ARCADY-7 was used for geometric analysis. First the discomfort level was determined using statistical analysis. The results revealed that elderly road user's as a driver, bicyclists and pedestrian are facing an unprecedented discomfort level while negotiating a roundabout. This study also helps in reducing the discomforts level and accident risk.**

***Index Terms*—intersection, elderly users, geometry, traffic, ARCADY**

I. Introduction

The function of the intersection is to guide vehicles to their respective directions. At the intersection, vehicles are moving in a different direction have to occupy the same space at the same time. These traffic intersections create complex locations in any urban arterial. In addition, the pedestrians also look for the same space for crossing. Drivers have to make in a split of second decision at an intersection by considering his route, intersection geometry, speed and direction of other vehicles, etc. A small error in judgment can cause severe accidents. It also causes a delay, and it depends on the type, geometry, and type of control. Overall traffic flow depends on the performance of the intersections. It also affects the capacity of the road.

The elderly population is growing at a considerably faster rate than that of the world's total population, which is about 1.2% against the other age-group (0.6%) [1]. In other terms, the number of elderly persons has been tripled over the last 50 years and will more than a triple population over the next 50 years [2]. In India, about 9.6 million people live in age group of 60 and over, which is an alarming group of the population as traffic commuters. As per Situation Analysis of India in 2011, projected population of the elderly people over 60 years will be 19.5 million in 2030 and 30.5 million in 2050 [3]. As the elderly population is more than 7% in India, for this reason, it can be considered as beginning "aging India" in 21st century [4]. Road user characteristics of elderly as a driver, pedestrian and cyclist are highly affected as the age increases and have been experiencing more difficulties at intersections as well as other infrastructure elements. As per study, Indian traffic junctions are most dangerous spot and need better designing of such junction. The data show at least 75,200 people lost their lives in crashes at traffic crossings in 2013, which is over 50% of the total deaths on Indian roads [5]. At T- intersection, about 25,800 fatalities were recorded and 13,500 fatalities at Y-junctions in the year 2008-2009. Four-arm junctions registered nearly 10,800 fatalities, and about 7,800 people lost lives at staggered junctions [5]. The studies were undertaken in Indian metro cities such as Delhi, Bangalore, Hyderabad, Pune, Pondicherry and other places. It was stated that pedestrians, motorized two-wheeler with rider and cyclists constitute more than three-fourth of those killed and injured in India [5]. The involvement of elderly drivers in crashes may be due to aging, medical/physical condition, driver errors, and certain environment conditions may responsible for the increased risk of fatality in crashes [6]. Elderly drivers are involved proportionately more in low-speed crashes at the intersection due to declining physical ability [7]. In daylight, fatal crashes occurred in + 60 years of age group due to multiple vehicle movements at the intersections [8]. It was noted that the prevalence impaired visual acuity (worse than 20/40) was significantly higher among the elderly road users. This driving situation, including driving at night and on high traffic roads causes driving discomfort [9]. As the color perception also declines as the age increases, and this may cause difficulties in the identification of significant and marking at intersections [10]. Elderly cyclist looked more frequently down at the road than in the traveling direction. It was noticed that, the young road users looked mostly straight ahead while cycling [11]. This tendency also increases the accident risk. The prevalence of hearing impairment increased with age, i.e. 6.1% of hearing loss in the elderly by age >= 65 [12]. The walking speed of the younger pedestrian was observed at 1.51m/s against elderly speed 0.75 m/s [13]. Event the judgment and reaction time was found 30 to 50% longer than that of young people. Even +60 age-group people may pose a hazard to themselves and other road users [14].

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Hence, it is necessary to consider elderly road user characteristics as important parameters during for intersection planning and designing. It increases the efficient mobility and safety at roundabouts or signalized, un-signalized intersections. Based on literature and study, an analysis was performed to define maneuverability of elderly road users at roundabout. It also illustrates the effect and possible remedial measures for elderly road users at roundabout intersection.

Figure 1. Pictorial view of survey location

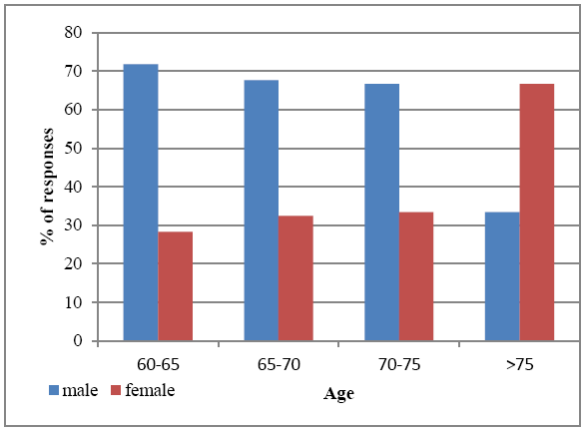

Figure 2. % of respondents

II. Study Area and Methods

The study area was chosen, where elderly road users' trips were more in the morning and evening. A short questionnaire was formulated based on the pilot survey. The elderly road users difficulties, judgment (gap finding), physical health while negotiating a roundabout or U- turn, recognizing the shape and size of the roundabout and marking and signage, etc. For field survey questionnaire script was prepared, which contains physiology and psychological characteristics of elderly road users (60+). The information was collected by face to face discussion regarding real traffic condition and their physical and mental comfort while negotiating roundabouts (area 2668 m^2) in Surat (Gujarat, India) as shown in Fig. 1. The 270 respondents were surveyed after classification into four categories such as 60-65, 65-70, 70-75 and >75 and also according to their gender. The survey respondents of all age group as shown in Fig. 2. In all age group, response from the male elderly users were more except age group >75. The answers to the questionnaire were statistically analyzed to measure the comfort of elderly as road user as shown in Fig. 3.

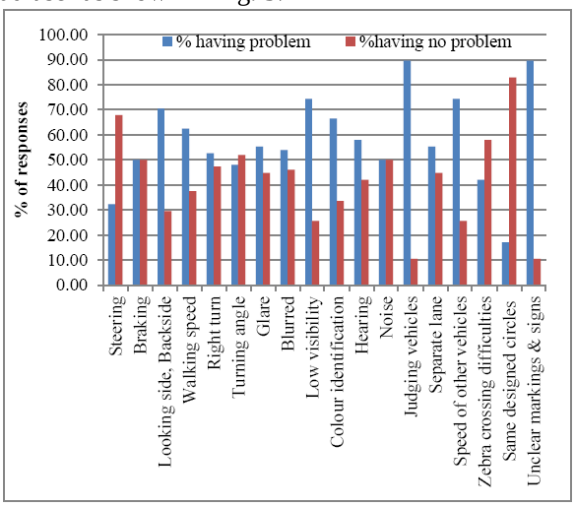

Figure 3. Percentage of response for all age group

Videography survey recorded the real time, maneuverability of elderly road user. Fig. 4 shows vehicular percent wise distribution. Two wheelers comprise nearly 77% of the total number of vehicles while cars constitute about 14%, three wheeler 4% and 5% other vehicles in Surat city.

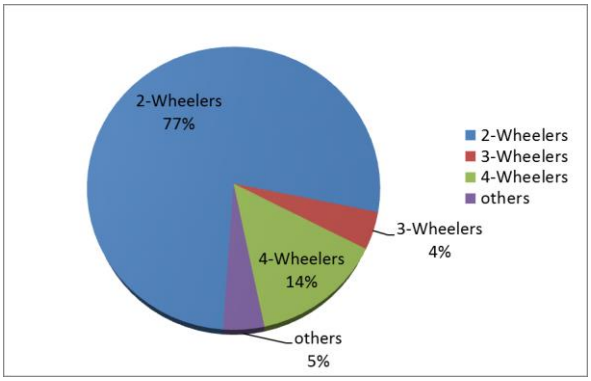

Figure 4. Vehicular Compositions

The percentage of turning movements at each of the approach entries, i.e. left (Dumas), straight (Umra), right (Athwa) and U-turn (SVNIT) traffic was also analyzed. The roundabout capacity was estimated using conventional method and ARCADY [15], [16].

Based on traffic survey data during morning peak hour, entry from Athwa arm has the maximum number of vehicles, i.e. 4206 PCU, whereas SVNIT arm has the least number of vehicles entry i.e. 483 PCU as mentioned in Table I. Similarly, for an evening peak hour, Dumas arm has the highest entry, i.e. 3134 PCU, and SVNIT arm still have lowest entry volume, i.e. 207 PCU as mentioned in Table II.

The capacity of the roundabout is found out by conventional method (Wardrops model). The geometric features are considered for calculating the capacity of

roundabout i.e. weaving width, entry road width, length of the weaving section, width of weaving and non- weaving section. The capacity of the roundabout for existing dimensions of the road is found, and present traffic volume is calculated by Videography survey. From the analysis, it is observed that, the present entry volumes of all approaches are significantly more than its capacity. The roundabout capacity was estimated using a conventional method is shown in Table III and Table IV.

TABLE I. CVC FOR ROUNDABOUT OF MORNING PEAK HOUR PCU/HR

	ATHWA			SVNIT			DUMAS			UMRA		
Mode	SVNIT	Dumas	Umra	Dumas	Umra	Athwa	Umra	Athwa	SVNIT	Athwa	SVNIT	Dumas
4W	28	1036	58	7	3	13	34	695	16	88	5	65
2W	155	1371	96	16	5	15	26	629	17	220	17	38
3W	15	491	40	2	3	10	17	275	2	92	2	15
LCV	2	32	5	3	1	0	4	19	0	5	0	0
Bus	0	199	28	0	0	0	0	98	0	0	0	17
Truck	0	36	0	0	0	0	0	0	0	0	0	3
Cycle	10	0	5	4	2	0	2	8	3	10	3	1
Total	292	3609	305	237	100	146	126	2155	62	753	58	370
	4206			484			2343			1181		

TABLE II. CVC FOR ROUNDABOUT OF EVENING PEAK HOUR PCU/HR.

	Athwa			SVNIT			Dumas			Umra		
Mode	SVNIT	Dumas	Umra	Dumas	Umra	Athwa	Umra	Athwa	SVNIT	Athwa	SVNIT	Dumas
4W	14	809	80	8	1	16	7	991	16	52	2	33
2W	68	1079	151	42	11	117	24	1578	17	148	10	42
3W	2	330	47	2	0	1	5	348	2	34	3	5
LCV	5	33	6	1	0	1	0	44	0	6	0	0
Bus	0	16	2	0	0	0	0	67	0	3	0	0
Truck	0	10	0	0	0	0	0	0	0	0	0	0
Cycle	19	1	9	0	2	5	1	31	3	3	2	1
Total	108	2278	295	53	14	140	37	3059	38	246	17	81
	2681			207			3134			344		

TABLE III. TRAFFIC SCENARIO IN MORNING PEAK HOUR

Mode	Weaving width (m)	Entry Width (m)	Width of non-weaving section (m)	Length of weaving the section (m)	Capacity of the roundabout by formula PCU/hr	Present traffic PCU/hr
SVNIT -Dumas	10	7.5	13.5	12	2234.4	4696
Dumas-Umara	10	10.5	12.5	11	2221.66	4767
Umra-Athwa	10.5	9	12.5	8.5	1857.98	2894
Athwa-SVNIT	10	10.5	15	12	2582.73	3544

TABLE IV. TRAFFIC SCENARIO IN EVENING PEAK HOUR

Mode	Weaving width (m)	Entry Width (m)	Width of non-weaving section (m)	Length of weaving the section (m)	Capacity of the roundabout by formula PCU/hr	Present traffic PCU/hr.
SVNIT - Dumas	10	7.5	13.5	12	2150.55	2508
Dumas-Umara	10	10.5	12.5	11	2225.86	2542
Umra-Athwa	10.5	9	12.5	8.5	1834.2	3288
Athwa-SVNIT	10	10.5	15	12	2404.53	3206

TABLE V. CAPACITY ANALYSIS OF ARCADY (MORNING PEAK)

Arm	Total Demand (PCU/hr.)	Queue (PCU)	RFC	LOS
Athwa	2394	1237.38	1.42	F
SVNIT	261	483.00	Max.	F
Dumas	2952	3.15	0.75	A
Umara	361	500.09	1.74	F

ARCADY (Assessment of Roundabout Capacity and Delay Version) is a software package for predicting capacities, queues and delays at roundabouts and mini-roundabouts. The program uses empirical formulae for calculating the capacity of each entry arm as a function of the circulating flow crossing in front of the entry. The operation of the roundabout as a whole is calculated on the basis of the common circulating carriageway links the entry to the roundabouts. Queues and Delays are calculated using time-dependent queuing theory. The method treats the whole range of demand and capacity and takes proper account of the statistical nature of traffic and the variations with time of demand and capacity. The capacities analysis shows that the existing capacity of the roundabout does not satisfy the present traffic inflow as shown in Table V & Table VI.

TABLE VI. CAPACITY ANALYSIS OF ARCADY (EVENING PEAK)

Arm	Total Demand(PCU/hr.)	Queue(PCU)	RFC	LOS
Athwa	2394	2.93	0.74	A
SVNIT	261	4.41	0.83	F
Dumas	2952	158.03	1.05	F
Umara	361	243.28	5.30	F

The above ARCADY analyzes show that circulating flow is highest at Umara and SVNIT. This phenomenon was noticed because of high entry flow through Dumas's and Athwa arm and consequently higher delay as a mention earlier section. As traffic flow is more in the evening peak hour in Dumas to Athwa arm, for this reason, it also has the high queuing vehicles length and delay. High traffic flowing from Dumas's arm leads to high circulating flow at Umra's's arm, causing more delay and queue at Umra's arm as well. The entry volume and circulating volume were found more towards SVNIT - Athwa's Arm and weaving traffic is more in Athwa-SVNIT and Dumas-Umra. As inflow traffic volume is higher than the design capacity of the roundabout, which creates an unfavorable situation for elderly as a driver/pedestrian/cyclist to find the gap or negotiate his/her vehicles.

III. Result and Discussion

Based on the 270 sample survey data, of elderly road users, it was observed that among age-groups 60-65, 65-70 and 70-75. The male elderly road users were more than female elderly road users as drivers, pedestrian, and cyclist. As the analysis shows that, the steering movements are more problematic for age-group of 65-70 and braking problems for age-group of 70-75 and looking aside-backside for the age-group of 60-65 under the male road users. The female road users, steering is more problematic for the age-group of 60-65 and braking and looking aside-backside is more problematic for the age-group of 65-70.

Regarding vision, glaring and blurred vision and color identification are more problematic for the age-group of 70-75 elderly road users. The low visibility is problematic for the age-group of 65-70 in all types of the elderly. Similarly, hearing is more problematic for the age group of 70-75 and noise is more problematic for the age-group of 65-70 for the male road users. The female road users, hearing is more problematic for the age-group of 60-65 and noise is more problematic for the age-group of 70-75.

Right turning is more problematic for the age-group of 65-70 and turning angle is more problematic for the age-group of 60-65 for the male road users. As female road users, right turning and turning angle are more problematic for the age-group of 60-65. The traffic problem like gap finding, using separate lane and a zebra crossing are more critical for age-group of 70-75 in male and female. The vehicle speed is problematic for the age-group of 65-70 for male road users. The road geometric problems; such as to identify same designed circle and unclear markings & signs are more problematic for the age-group of > 75 for both male and female.

IV. Summary and Findings

The population of elderly road users is increasing rapidly globally as well as in India. Elderly road user's study shows that significant variation in traffic characteristics. As their physical and psychological characteristic are declines with age, which affect their mobility as a road user. The increased traffic and congested intersection create an unpleasant driving and walking situation to them. The elderly road user's physiological and psychological changes in traffic characteristics as a driver, pedestrian, and cyclist are highly affected as mentioned below:

The study reported that 57% elderly male and 44% elderly female has difficulty while using intersection after the age group of 60+. The analysis shows that 65% male and 56% female have steering, braking and looking side, back side problem while they are driving and walking. Motorized driving 68 % male and 86% female elderly drivers have been turning right problem, and 72 % male and 66% female drivers have turned angle problem. It was noticed that Ellery drivers have acuity problem such 60 % male and 73 % female also 62% male, and 50 % female has a hearing problem. For this reason, it was concluded that elderly road user has distinct traffic characteristics as compared to the conventional traffic characteristics.

The elderly people are at elevated risk of intersection crashes in both urban and rural areas as the traffic is increasing day by day. This traffic condition creates an unfavorable situation for elderly as a driver / pedestrian / cyclist.

Recommendation: It is suggested that signage for roundabout with name should be placed well in advance. The provision of a continuous sidewalk and crossing the intersection, through handrail, should be provided. Regulatory and warning signage should be provided larger than the prevailing specifications.

The forthcoming and preceding street-name at intersection should be provided. The survey suggests that placement of signage should place at upstream of the intersection and midblock locations. Provision should be made to reduce vehicle speed while approaching intersection with proper active and passive signage. When different street names are used for different directions at intersections, the names should be separated and accompanied by directional arrows on forthcoming and preceding street-name signs.

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