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Safety Interventions in Urban Planning For Vulnerable Road Users

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ABSTRACT*: The fast and unprecedented growth of urban centers has not resulted in safe travel. Deaths/ 100 accidents are much higher in many cities than the national average. The most vulnerable group of road users VRUs include Pedestrians, bicyclists and two wheeler riders comprising of 60-90% of the total fatalities in cities. At the city level, efforts to improve transport infrastructure often involve road widening, junction improvement for motorized vehicles, and construction of elevated roads. Infrastructure is not planned for majority VRU trips. This often limits the freedom of movement and safety of pedestrians and bicyclists and encourages private vehicle trips threatening sustainable urban transport needs. The paper summarizes various studies and accident prediction models developed for cities and conclude that promoting mixed land use to reduce trips, designing infrastructure keeping in mind the needs of VRUs and ensuring an easy and safe last mile travel after exiting a public transport may be some of the key interventions at the planning stage.*

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I. INTRODUCTION

For the first time since Independence, the absolute increase in Indian population is more in urban areas than in rural areas. The level of urbanization has increased from 27.81% in 2001 to 31.16% in 2011.(Census, 2011) Urban population contributes over 60% of India's GDP and it is projected that urban India will contribute nearly 75% of GDP in the next 15 years.

The high concentration of population and economic activities in urban centers has given rise to high concentration of passenger and goods vehicles in Indian cities. The growth of road infrastructure has not been able to cope up with this growth. Table 1 shows that registered motor vehicle growth rate in India since last 5 decades is above 10% but our road network growth rate is only 3.6% and that of Urban road network is less than 5% during this period though registered motor growth in Indian cities is much higher than the national average.

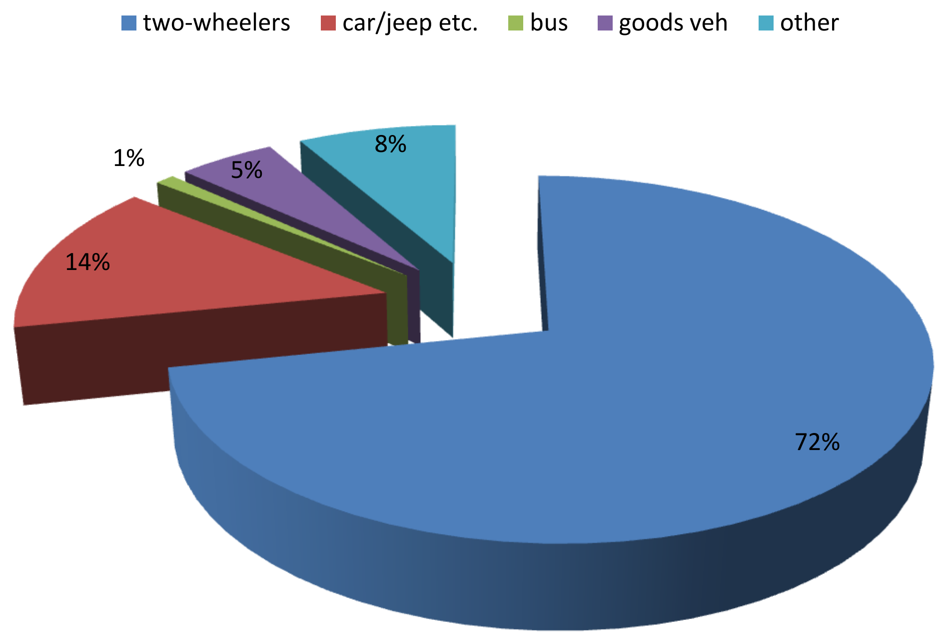
It is obvious from the Fig. 1 that unlike developed countries two-wheelers share in vehicle population is much higher (71.8%) and cars are just 14%. VRU and public transport trips constitute majority of trips in Indian cities with 22-57% walk trips, 3-20% cycle trips, 6-30% two wheeler trips and 5-44% public transport trips, proportion varies according to the size of the city. Car trips are just 1-28% in all cities and further less 1-12% in million plus cities (Fig.2). 80 per cent of these trips are less than 10 km in length and 70 per cent of the trips are less than 5 km even in big cities like Mumbai and Hyderabad. In cities like Pune 97 per cent of the trips are less than 10 km and 80 per cent are shorter than 5 km. The average trip length in medium and small size cities is less than 5 km, which makes non-motorised transport an attractive option for commuting. (NTDPC, Vol 3, Part 2).

At the city level, efforts to improve transport infrastructure often involve road widening, junction improvement for motorized vehicles, and construction of elevated roads. Though walking, cycling and two-wheeler use still constitute majority of trips (58-88%) the infrastructure is not planned for them. This often limits the freedom of movement and safety of pedestrians and bicyclists and encourages private vehicle trips resulting in a vicious circle of more unsafe and congested roads giving way to deteriorating air quality, noise, habitat loss and fragmentation, and increasing number of accidents. To come out of this vicious circle the road infrastructure and land use planning in Indian cities needs to be revisited.

Table 1: Growth rate (in %) of Road Networks and Total Registered Motor Vehicles

Period	NHs	SHs & OPWD Roads	Rural Roads	Urban Roads	Project Roads	Total	Total Registered Motor Vehicles
2012/1951	2.2	3.2	4.4	-	-	4.2	6.4
1961/1951	1.9	4	-0.5	-	-	2.7	8.1
1971/1961	0	2.6	6	4.5	-	5.7	10.9
1981/1971	2.9	4.5	5.9	5.5	3.5	5.0	11.2
1991/1981	0.6	2.1	7.2	4.3	1.2	4.6	14.8
2001/1991	5.5	3.1	4.6	3.0	0.6	3.8	9.9
2012/2002	2.8	3.6	3.3	6.4	2.9	3.6	10.5

Source: Basic Road Statistics of India, 2011-12, Government of India, Ministry of Road Transport And Highways, Transport Research Wing, New Delhi, 2013; www.morth.nic.in



Source: Ministry of Road Transport and Highways (2012).

Fig. 1: Composition of India's Vehicle Population, 2011

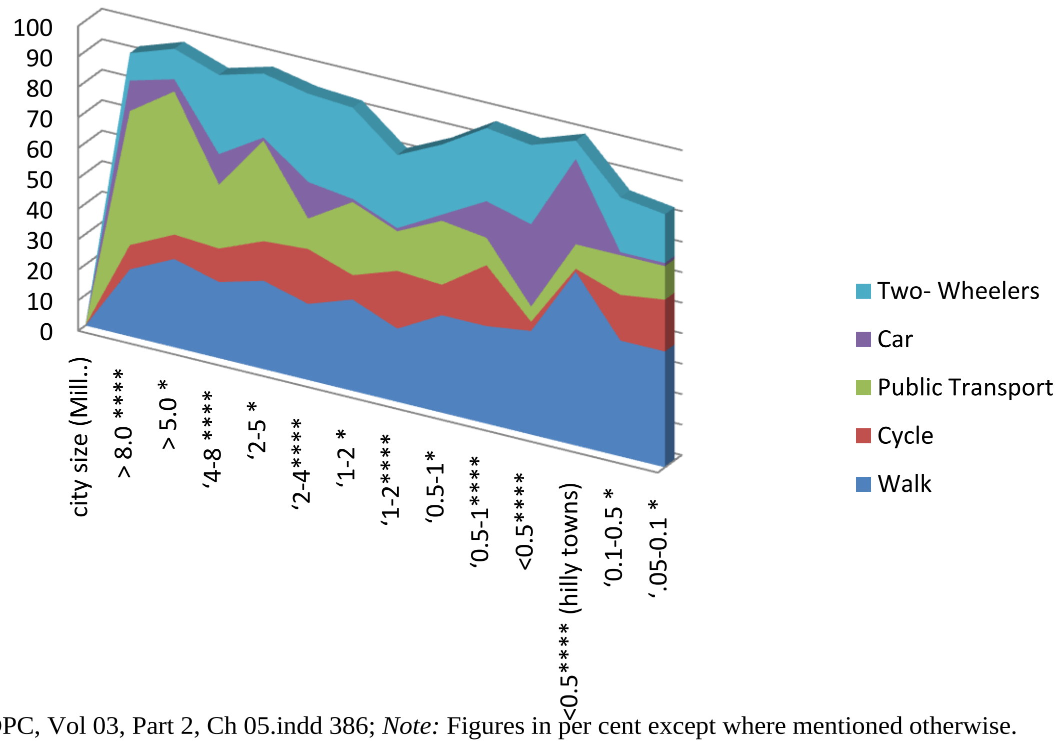
The present study summarizes various studies and predictive models developed for cities to study the impact of land use planning, infrastructure design, network characteristics and socio-economic characteristics on safety of the most vulnerable road users travelling by public transport or by non-motorized means.

II. ROAD ACCIDENTS, INJURIES, DEATHS AND SEVERITY IN MILLION PLUS CITIES

In 2013, the total number of road accidents that occurred in urban areas were 45.8%; urban shares of road fatalities and injuries were 38.2% and 40.2% respectively. (Table 2) Census of India 2011 has reported 54 Million Plus Cities. Out of them, 50 cities accounted for a share of 22.7% in total road accidents in the country, 12.4% in total persons killed and 16.2% in total persons injured. Accident severity (road deaths/100 accidents) for many cities was alarming with Amritsar at the top (72.6%). (Fig.4). In many cities road accident share in all accident deaths is more than the national average (45%) with highest 92.6% road fatalities in Lucknow (Fig.5).
Pedestrians, bicyclists, and motorcyclists are the groups most likely to be hurt by other road users (Mayou & Bryant, 2003) commonly known as Vulnerable Road Users (VRU). VRUs comprise of 60-90% and Motorcyclists alone about 25% of the total road fatalities in Indian cities. On the other hand heavy vehicles like trucks and cars are associated with most of fatal road crashes.

The data clearly shows that in India safety policies must focus on issues concerning the safety of VRUs so as to arrive at sustainable urban transport and reduce heavy accident costs accounting 3% of India's GDP at

Fig. 2: Modal split in Indian Cities, consolidated figures



Source: NTDPC, Vol 03, Part 2, Ch 05.indd 386; *Note:* Figures in per cent except where mentioned otherwise.
* Tiwari (2011); ** Pendakur 2002 and World Bank 2002; *** Data from various City Development Plans available at http://www.jnnurm.nic.in/ (accessed on 20 January 2014); **** WSA,GoI (2008).

Table 2: Total Accidents, Persons Killed and Injured in Rural & Urban Areas during 2013

Category	Total Accidents	Person Killed	Person Injured
Urban Area	2,22,883(45.8)	52,603 (38.2)	1,99,024(40.2)
Rural Area	2,63,593 (54.2)	84,969 (61.8)	2,95,869 (59.8)
Total	4,86,476	1,37,572	4,94,893

Note: Figures in parentheses indicate share of the total.

present. Policies need to be developed so that these groups may be included as an integral part of traffic in the planning of new highway and area planning schemes.

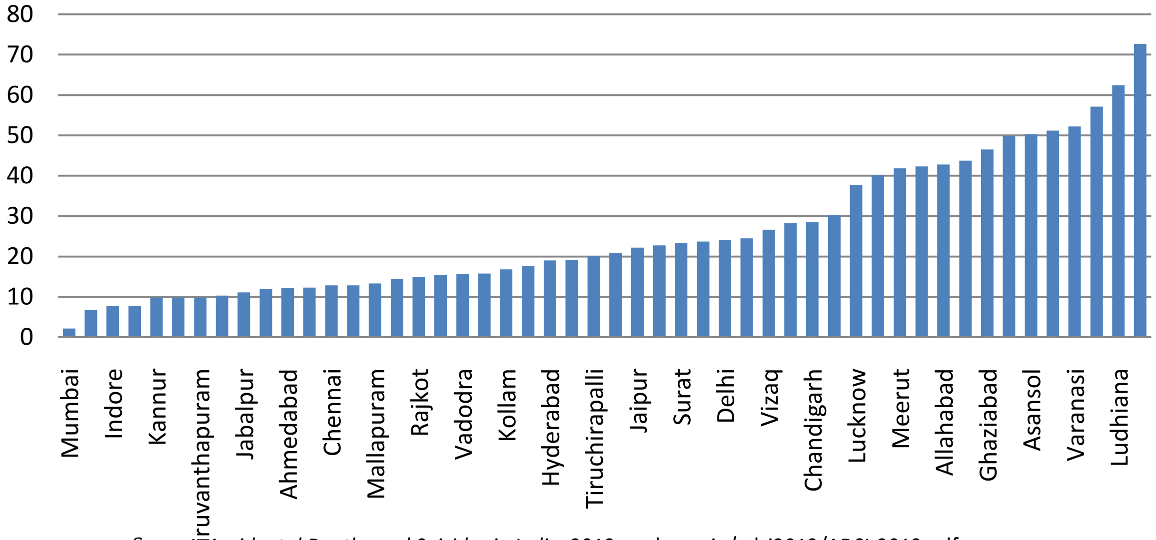
III. LITERATURE REVIEW

Road safety planning using Accident Prediction Models in the long term might be a more effective and sustainable road safety engineering approach rather than retrofitting measures after accidents (De Leur and Sayed, 2003; Lovegrove, 2007).

Unfortunately, not much research has been done on predictive modeling of accidents of vulnerable road users in India. Non-availability of quality accident data is the main hindrance in research in this direction. Mohan and Tiwari (2000) and Mohan (2002) have emphasized that the issues of vulnerable road users and public transport users ought to be incorporated in the planning. TERI (2008) study of the mobility needs of slum dwellers in Bangalore reveals that the travel needs of the urban poor, who constitute a chunk of the public transport users, are not met by the existing public transport systems. This can be ensured by providing bus routes reaching slum locations, locating bus stops within convenient walking distances to minimize walking time, and frequent bus services to minimize waiting times. Real time GPS (global positioning system) may be used in public transport vehicles to track vehicles, and warn about delays and breakdowns.

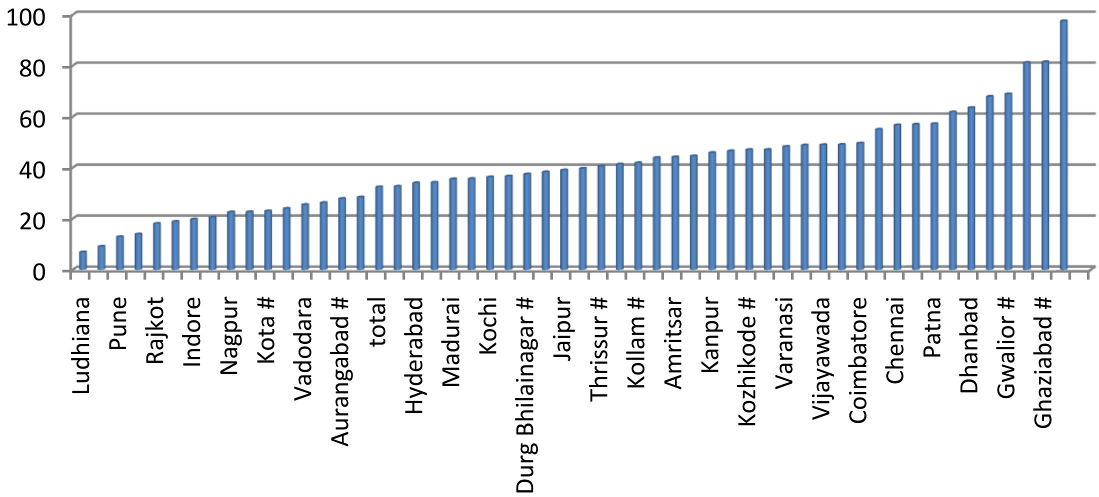
Many researchers have shown that increased use of bicycles reduces accidents. Osberg and Stiles (1998) compared bicycle use and road safety in Boston, Paris and Amsterdam, which have similar social-economics,

Fig. 4: Accident Severity in Select Cities 2013



Source: Accidental Deaths and Suicides in India, 2013, ncrb.gov.in/adsi2013/ADSI-2013.pdf

Fig. 5: Road fatalities in cities as % of Total Accidental deaths



Source: Accidental Deaths and Suicides in India, 2013, ncrb.gov.in/adsi2013/ADSI-2013.pdf

but very different levels of bicycle use: lowest use in Boston, slightly higher cycle use in Paris; and highest use in Amsterdam. They found that Amsterdam had the lowest total road fatalities rate, at 5.8 fatalities/100,000 population, despite experiencing the highest cyclist fatality rate of these three cities with 1.8 fatalities/100,000 population. Newman and Kenworthy (1999) reported that Amsterdam and Copenhagen are considered high bicycle use cities among developed countries, yet they suffer only half the road traffic fatality rate of US cities (5.8 fatalities for Amsterdam, 7.5 for Copenhagen and 14.6 fatalities/100,000 population for US cities on

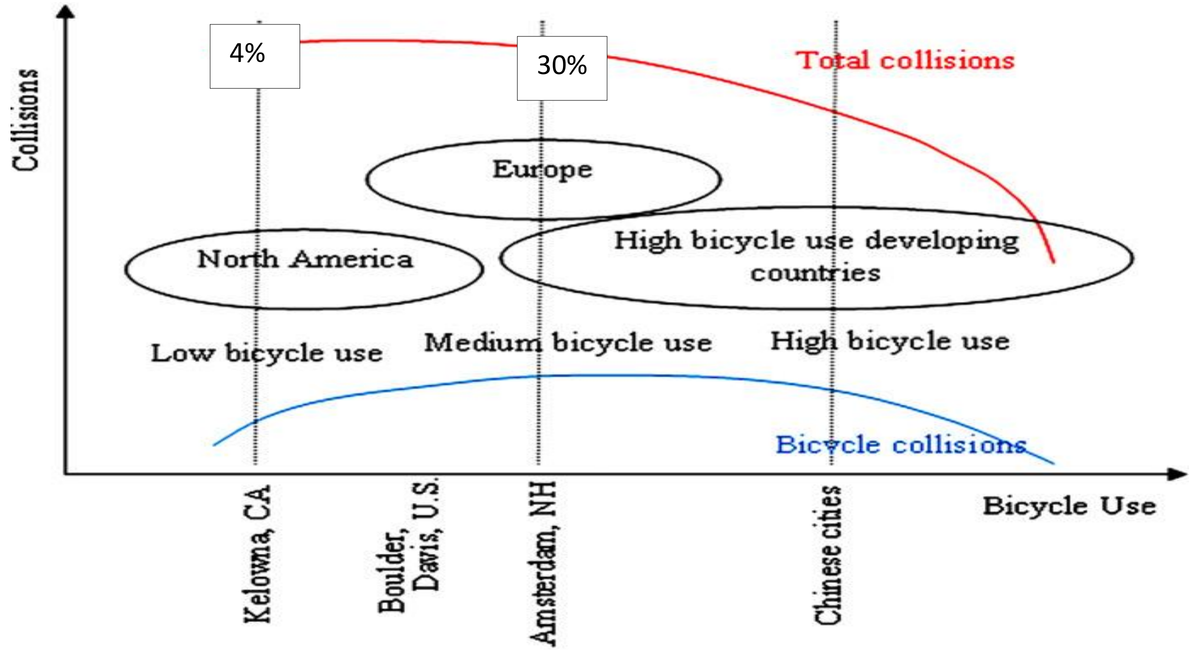


Fig. 6: Bicycle use and overall level of road safety
(Source: Wei and Lovegrove, 2012)

average). Marshall and Garrick (2011) examined the road safety data from 24 California cities and found that cities with higher bicycle use generally showed much lower risks of fatalities for all road users.

III.1BEHAVIOURAL STUDIES

Most pedestrian accidents are caused by misjudgments of velocities of motorized vehicles or distances (Hills, 1980), or failures to perceive them, either because of obstructions or because of attention failures. On the other hand, the drivers often overlook places where VRUs might be present and so fail to spot the VRUs (Hills, 1980; Moray, 1990; and Räsänen & Summala, 1998). Summala et al. (1996) showed that physical measures such as signs were reasonably effective in making the drivers look towards the cycle paths more often.

Interestingly, Jacobsen (2003) found that across several different countries and several different decades, as levels of pedestrian and bicyclist activity in a community rose, the per capita risk for pedestrians and cyclists fell. This effect must come about because drivers “adapt their behavior in the presence of people walking and bicycling” (p. 205).

Segregation of VRUs from main traffic stream by providing separate tracks was not supported by research. Studies suggest that off-road tracks are even more dangerous places for cyclists to travel than roads (Aultman-Hall & Adams, 1998; Aultman-Hall & Hall, 1998; Aultman-Hall & Kaltenecker, 1999; Garder, Leden, & Thedeen, 1994; Moritz, 1998). This suggests that attention should be focused on making the on-road environment as safe as possible rather than taking cyclists off the road.

Moreover, it is probable that any segregated route for pedestrians or cyclists would increase journey times, which would act as an unfortunate disincentive in societies that want to get more people cycling and walking for the health and environmental advantages that these offer (Hillsdon & Thorogood, 1996; Mutrie et al., 2002; Ogilvie et al., 2004).

III.2. MICRO-LEVEL ACCIDENT PREDICTION MODELS

III.2.1 ACCIDENT PREDICTION MODELS FOR VRUS

Brude and Larsson (1993) collected data at 377 intersections with more than 100 pedestrian or cycle movements per day, from 30 towns in Sweden. Their model forms were power functions with two leading variables as bases: the incoming motor vehicles (AADT) and the number of passing cyclists per day. Results showed that the risk to cyclists increased with increased motor traffic flow, but decreased with increased cyclist flow.

Turner and Francis (2003) developed micro-level model with Poisson or NB regression methods for pedestrian and cyclists, based on data from three cities in New Zealand. Study results indicated that the overall pedestrian and bicycle collision frequencies increased with increased VRU flows, but collision rates/pedestrian and per cyclist decreased with increased VRU flows.

Machsus et al. (2013) developed predictive models to overcome motorcycle accidents on arterial roads in Surabaya, Indonesia where motorcycle accidents are 70.7 % of the total traffic accident. Generalized linear models approach, with a Poisson distribution and logarithmic link function was used for modeling. The model result indicates that for every 5 access point increase/km of road increase accidents by 10%.

Harnen et al. (2003) attempted to develop a prediction model for motorcycle crashes at non-signalized intersections on urban roads in Malaysia using Generalized Linear Modeling approach. The final model revealed that doubling of all vehicles entering the intersection will result 36% increase in motorcycle crashes; 10 km/h increase in approach speed is expected to cause a 27% increase in motorcycle crashes and widening the lane on major and minor roads by 0.50 m is expected to reduce motorcycle crashes by about 5% and about 4% respectively. However, the number of lanes marginally affects motorcycle crashes, only about 1%. Motorcycle crashes at intersections without a shoulder were about 5% higher than those at intersection with a shoulder width wider than 1.00 m. Motorcycle crashes at non-signalized intersections located within commercial areas were higher than those located within non-commercial areas.

III.2.2 EFFECT OF SPEED ON ACCIDENTS

Machsus et al. (2013) reported that for every 5 km/hr speed increment the motorcycle accidents on arterial roads rise by 28.39%. Taylor et al. (2000) studied in detail the effect of speeding on urban accidents using Multivariate regression modeling. The accident frequency on urban classified roads rises approximately with the square of the mean traffic speed. Also, the percentage reduction in accident frequency per 1mile/h reduction in mean speed had been shown to vary according to the road type and the average traffic speed. It was about 6% for urban roads with low average speeds, 20miles/h; about 4% for medium speed urban roads; about 3% for the higher speed urban roads, 34miles/h.

The accident frequency on urban classified roads had been reported to rise exponentially as the coefficient of variation of speed rose; a rise of 0.025 in the coefficient of variation resulting rise to accident frequency by 15%. Thus the accident frequency is very sensitive to any increase in the variation of speeds about a given mean speed. The accident frequency also found rising with the proportion of drivers speeding, if speeders double, the accident frequency rises by 10%. And for every 1mile/h increase in average speed of the speeders, the accident frequency rises by 19%.

III.3. MACRO-LEVEL BICYCLE ACCIDENT PREDICTION MODELS

From the macro-level aspect, Jacobsen (2003) examined the relationship between the numbers of pedestrians or cyclists and their collisions with motor vehicles based on five data sets from all over the world. Results showed that the number of VRU collisions would increase at roughly 0.4 power of the measure of people walking or bicycling. Thus, a community doubling its bicycle use could expect a 32% increase in injuries (20.4 = 1.32). Although the VRU injury frequency increased in absolute terms, but the probability that a motorist might collide with an individual VRU would decline with the roughly 0.6 power i.e. by 51%. Similar results were also reported by Jonsson (2013), Robinson (2005), Leden (2002), and Leden et al., (2000).

Kim et al. (2010) examined the relationships between different types of collisions and independent variables in demographic, land use, and roadway accessibility fields in Honolulu. A binary logistic regression was chosen to model such relationships. The results from bicycle collision models suggested that demographic variables such as job count and the number of people living below the poverty level were significant and positively associated with bicycle collisions; accessibility variables such as the number of bus stops, the bus route length, and the number of intersections were also positively associated with bicycle collisions.

Graham and Glaister (2003) examined the role of urban scale, density and land-use mix on the incidence of road pedestrian casualties using negative binomial models. The study concluded that the incidence of pedestrian casualties and injuries were higher in residential areas than in business areas. In addition, the relationship between urban density and pedestrian casualties were found in quadratic form with incidents reduced in highly populated wards.

Aguero-Valverede and Jovanis (2006) developed Full Bayesian (FB) and negative binomial models to carry out spatial analysis of fatal and injury crashes in Pennsylvania. The study concluded that counties with a higher percentage of the population under poverty level, and increased road mileage and road density have significantly increased crash risk.

IV. CONCLUSIONS

The model results indicate, Motorcycle accidents could be reduced by controlling access on segments and intersections, by providing shoulders or separate lanes at intersections, by reducing motorized traffic on the roads and intersections and by increasing proportion of cyclists. Pedestrian and bicycle accidents prediction models and behavioral studies suggest that accidents could be reduced by promoting walking and cycling trips and by making road environment safer for pedestrians and cyclists by providing lighting, signage, marking on the roads rather than providing separate track for cyclists. Intelligent application of speed enforcement targeting speeders with different strategies on different roads will be required. Speed enforcement on typically busy main roads in towns with high levels of pedestrian activity, wide variation in speeds, and high accident frequencies will be more effective than on more modern, well engineered suburban types of roads. Macro-level accident prediction models suggest that promoting mix land use and high density settlements and public transport usage keeping in mind the population living in slums and low income neighborhoods will reduce accidents.

Bicycles traveling at an average speed of 15 km/h are well suited to the short and medium-distance trips and best suited for trips up to 5 kms, which constitute about 70% trips in Indian cities. These trips also include entry and exit trips from a public transport. If these last mile trips could be made safer and convenient, public transport ridership will also improve and personal transport trips will come down. According to the generalized model suggested by Wei and Lovegrove, (2012) (Fig. 6), by promoting bicycle use in our cities the safety of vulnerable road users could be enhanced. Data suggests ample scope for this.

This could only be achieved if the design of urban infrastructure undergoes a paradigm shift. Existing design standards do not account for conflicting demands of local traffic which mainly comprises vulnerable road users and through traffic which is predominantly of cars, and trucks, resulting in sub-optimal conditions, i.e., long delays for through traffic and safety hazards for local traffic especially at off peak hours. The design approach must not only account for the needs of motorized vehicles of clear roads for uninterrupted traffic flow, but at the same time they must also address the needs of bicyclists and pedestrians for shady trees, shelters, and facilities like drinks, food and bicycle repair shops, etc., at shorter distances. (Tiwari, 2000) A pedestrian or bicyclist would prefer not to use an underpass or over-bridge just because it is safer to do so. For this group of users convenience is an overriding priority. As the model results indicate, emphasis must be given to redesign the road cross section setting more exclusive space for pedestrians and bicyclists, giving priority to them over cars at certain places. To promote research on predictive modeling of accidents quality of data needs to be enhanced through GIS based black spot mapping and videography at selected locations.

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