



Publications

Books & Monographs

Intelligent Transportation System (ITS) and Urban Transport

D. Mohan, (2011). *Transportation Research & Injury Prevention Programme, Indian Institute of Technology Delhi, New Delhi.*

Role of Non-motorized Transport in Movement of Freight in Cities

G. Tiwari, H. Jain and SSLN, Sarma (2011). *Transportation Research & Injury Prevention Programme, Indian Institute of Technology Delhi, New Delhi.*

Research Papers

Analysis of Road Traffic Fatality Data for Asia

Mohan, D. (2011) *Journal of the Eastern Asia Society for Transportation Studies, Vol.9, pp 1786-1795.*

Systematic Identification of Bottlenecks on Urban Arterials: A Case Study

Mohan Rao and K. Ramachandra Rao (2011). *Urban Transport Journal, Vol 10, 86-98.*

Heterogeneous Traffic Modelling: A Complete Methodology

Mallikarjuna and K. Ramachandra Rao (2011). *Transportmetrica, Vol. 7., Issue 5, 321-345.*

Study of the Influence of Lateral Distribution of Traffic on Asphalt Pavement Design

S. Sinha, K. Ramachandra Rao, S.K. Deb, J.K. Das(2011). *1st conference of Transport Research Group of India (CTRG), Bangalore, Dec 2011.*

Review of Environmental Impact – Assessment and Reduction in Road Rehabilitation by Adoption of New Technology

K. Bhandari, G. Tiwari, V. Arora, K Ramachandra Rao, Sangeetha. (2011) *1st conference of Transport Research Group of India (CTRG), Bangalore, Dec 2011.*

Evaluating the Impact of Free Left Turns on Traffic Behavior at Signalized Intersections in Heterogeneous Traffic Conditions.

Gadepally, S. B. Ravi, Geetam Tiwari(2011). *Journal of the Eastern Asia Society for Transportation Studies, Vol. 9, pp 1700-1714.*

Modification of a Highway Capacity Manual Model for Evaluation of Capacity and Level of Service at a Signalized Intersection in India.

Tiwari G. Khatoon M. Singh N, Choudhary, P., Fazio, J.(2011). *Journal of the Eastern Asia Society for Transportation Studies, Vol. 9, pp 1558-1571.*

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Financial Operational and Safety Performance of Bus System : Case Study DTC

Ghosh, Abhjit, G. Tiwari(2011) . *UMI 2011Research Symposium, Delhi 3-5 December.*

Statistical Analysis to Measure Pedestrian Risk at Foot of Flyover

Khatoon, M., G. Tiwari, N.Chatterjee(2011), *UMI 2011Research Symposium, Delhi 3-5 December.*

Accessibility and Safety Indicators for All Road Users: Case Study Delhi BRT

Tiwari, G. and Jain, D(2012). *Journal of Transport Geography, 22, 87-95.*

Effect of Muscle Contraction In High Speed Car-Pedestrian Impact - Simulations for Walking Posture

A Soni, A Chawla, S Mukherjee, R Malhotra (2011) *International Journal of Vehicle Safety, Vol 5, NO. 2, pp 101-116.*

Effect of Impactor Mass on the Response of Knee Joint During Finite Element Simulations

Soni A, Chawla A, Mukherjee S (2011). *Int J of Vehicle Safety, Vol 5, No 2, 2011, pp 189-195.*

Studying the Impact of Various Inventory Policies on Supply Chain with Intermittent Supply Disruption.

Samvedi, A., and Jain, Vipul., (2011). *Proceedings of the Winter Simulation Conference, December 11-14, Arizona, Grand Resort, Tempe, USA.*

Minimizing the Vulnerabilities of Supply Chain: A new Framework for Enhancing the Resilience.

Soni, U., and Jain, Vipul., (2011) *Proceedings of the IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), 6-9 Dec, Singapore.*

Predicting Fractures Initiation, Propagation and Diversion in Long Bones Under Impact Using Drucker-Prager Blastic Model and Damage Modeling

Chawla, A., Mukherjee, S., Mike.W.J. Arun (2011). *American society of biomechanics, August.*

Dynamic Properties of the Shoulder Complex Bones

Mukherjee S, Chawla A, Borouah S, Sahoo D, Arun W J A (2011). *ESV 2011, paper no. 11-428.*

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Sankarasubramanian H, Mukherjee S, Chawla A,(2011) *ESV 2011, paper no. 11-0422, pp 1-8.*

Dynamic Properties of Human Cancellous Bones

Mukherjee S, Chawla A, Marwah K, Grover L, Keishing J, (2011), *ESV, paper no. 11-0429, pp 1-4.*

Research & Consultancy Projects

Sustainable Urban Transport in Less Motorised Countries: Research and Training

Sponsor *Volvo Research & Educational Foundations*

Team *D. Mohan, G. Tiwari, A. Chawla, S. Mukherjee, S.R. Kale, P. Mahajan, S. Sanghi, and N. Chatterjee*

Estimation of Emissions and Fuel Consumption of in-use Vehicles in Different Driving Conditions.

Sponsor *Petroleum Conservation Research Association*

Team *G Tiwari, S.R. Kale, K Ramachandra Rao and D. Mohan*

Promoting Low Carbon Transport in India

Sponsor *UNEP Risoe Centre, Denmark*

Team *G Tiwari, D. Mohan, S.R. Kale, K Ramachandra Rao and A. D. Sagar*

Review of Contractual Provisions, Establishment of Work-zone Safety Audit Procedure Conducting Work-Zone Safety Audit and Strengthening Work Zone Safety Implementation for Lucknow-Muzaffarpur National Highway Project (LMNHP).

Sponsor *National Highway Authority of India*

Team *K.N. Jha, G. Tiwari, K Ramachandra Rao, D. Mohan and S. Mukherjee*

Development of Toolkit on Road Safety Audits

Sponsor *Institute of Urban Transport (India)*

Team *G Tiwari, D. Mohan and K Ramachandra Rao*

Development of Toolkit on Public Transport and Accessibility

Sponsor *Institute of Urban Transport (India)*

Team *G Tiwari, D. Mohan and K Ramachandra Rao*

The Transportation Research and Injury Prevention Programme (TRIPP) at the Indian Institute of Technology Delhi, is an interdisciplinary programme focussing on the reduction of adverse health effects of road transport. TRIPP attempts to integrate all issues concerned with transportation in order to promote safety, cleaner air, and energy conservation. Faculty members are involved in planning safer urban and inter-city transportation systems, and developing designs for vehicles, safety equipment and infrastructure for the future. Activities include applied research projects, special courses and workshops, and supervision of student projects at postgraduate and undergraduate levels. Projects are done in collaboration with associated departments and centres at IIT Delhi, government departments, industry and international agencies.



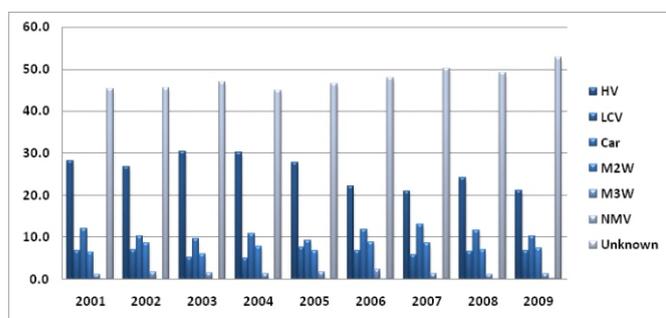
PEDESTRIAN FATALITY IN DELHI 2001 TO 2009 A TRIPP REPORT: EXCERPTS

Walking is the most sustainable and most used mode of transportation in Indian cities. The National Capital Territory of Delhi is spread over an area of 1,484 km² with a population of 13.9 million as per the 2001 census report. In Delhi around 21% of the trips are made by walking. As per the accident data (Delhi Police, 2009), among all road users in Delhi, the ones who are most exposed to risk are the pedestrians. Despite the given fatality rate of pedestrians, walking has the maximum modal share in Indian cities. 18.7% of the population in Delhi lives in slums areas. Thus in Delhi, a large group of the population cannot even afford subsidized public transport and low cost bicycles. They are dependent on walking to meet their daily travel needs. In addition, public transport users walk at least four times each day when they ingress/egress public transport systems. Pedestrians and public transport users together form the largest group of road users. Pedestrian deaths in Delhi are almost four times the national average. It is therefore, very important to analyze the pedestrian's crash and fatality data in order that the risks faced by them can be minimized while the transportation facilities are improved for motorized traffic.

The following table represents the year-wise variation in the number of pedestrians involved in road traffic rashes (according to police records).

Year	Pedestrians Involved			
	One	Two	Three	>Three
2001	3851	230	48	66
2002	3651	204	27	56
2003	3639	158	51	26
2004	3819	144	39	19
2005	3960	208	69	55
2006	3909	204	51	57
2007	3324	420	81	109
2008	3673	242	84	59
2009	3193	448	138	66

Involvement of the different types of conflicting vehicles in pedestrians' fatalities as a percentage of the total road fatalities over the years has been plotted in the following bar graph as shown in the figure below:



The following points are evident from the data:

- In about 45-52% of pedestrian fatalities, the type of impacting vehicle has not been reported. Therefore it will not be very fair to judge on the basis of this data.

- However, if we infer on the basis of the data in hand it can be easily seen that
 - a) although very few HCVs are present in the traffic stream, they contribute about 20-30% of pedestrian fatalities.
 - b) LCVs are involved in 5-8% of pedestrian fatalities. That may be because there are very few LCVs present in the traffic stream.
 - c) Cars contribute about 9-12% of the total pedestrian fatalities.
 - d) Motorized two wheelers contribute about 6-8% of the total pedestrian fatalities.
 - e) Motorized three wheelers contribute about 1-2% pedestrian fatalities.

When we look at the data on the basis of the reported time of pedestrian fatalities, it is evident that:

A number of pedestrian fatalities have occurred at an unknown time; i.e. the time of occurrence of the pedestrian fatality has not been reported in many of the cases.

- However, if we infer on the basis of the pedestrian fatality data in hand it can be easily seen that:
 - a) From the year 2001-2009, the pattern of pedestrian fatalities is quite uniform throughout the day. Though at different times of the day the pedestrian volume highly varies as in peak hours and non-peak hours. Thus we can conclude that the pedestrian road fatality rate is largely unaffected by pedestrian volume on the road.
 - b) A very apparent fact is that even in the odd hours (very late night) when pedestrians are very sparse, the number of pedestrian fatalities are significant.

GIS Tool

Further we analyzed the pedestrian fatal accidents in four years from 2006-09 using (Geographic Information System) GIS.

Several analytical tools and techniques are available to analyze crash data. However, questions such as "where are most of the crashes occurring and why?" is difficult to answer. These questions can be easily addressed in a GIS environment.

A geographic information system (GIS) integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. GIS allows us to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts.

Schneider et al. (2001) explain the importance of methods to identify where the pedestrian crash problem exists so that a greater number of pedestrian crashes can be prevented in the future. Studies in recent years have focused on the issue of safety analysis using GIS techniques. Even though GIS techniques are not extensively used in the safety field, they have greater potential to improve crash location evaluation. Simple crash plotting, or geocoding crash locations, is the most common GIS technique used for safety studies. GIS turns statistical data, such as crashes and geographical data, such as roads and crash locations, into meaningful information for spatial analysis and mapping. Using GIS it is relatively simple to combine information received annually on crashes and determine any correlations such as types of street and adjacent land use. GIS also assists in identifying any factors that contribute to those crashes and/or potential solutions to reduce those crashes.

Analysis and Observations with GIS

The top ten roads are pointed out, providing count of the number of fatal and non-fatal accidents on each road. It is important to note that; the statistics of all the accidents and not just those involving pedestrians as shown in the following table. This table is in decreasing order of fatalities on major roads rather than non-fatalities.

- The Ring road tops the list with 793 fatal accidents and 1818 non-fatal accidents, which comprise of about 10% of total fatal accidents (8,503) and 7% of total non-fatal accidents of Delhi (25,353)
- Count of accidents increased per year over ring road and outer ring road.

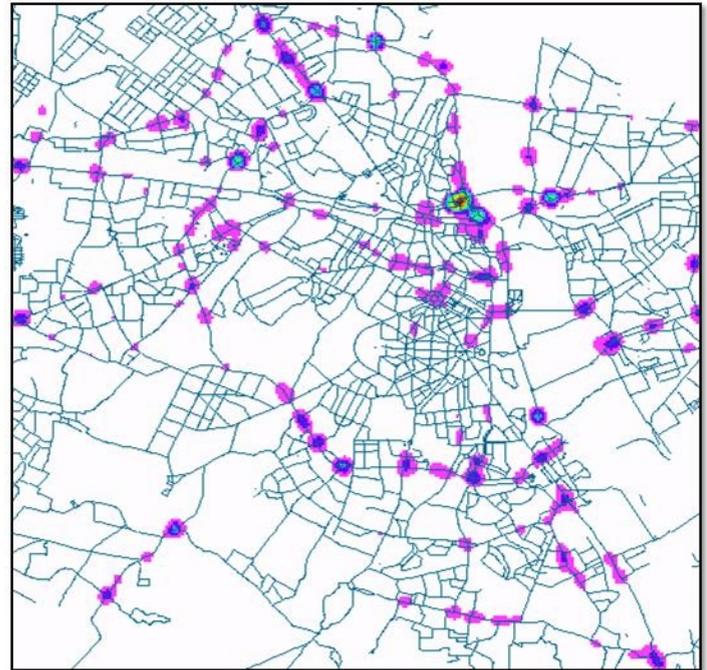
Major roads of Delhi in decreasing order of accidents occurred 2006-2009

Road Name	Fatal	Non-Fatal
Ring Road	793	1818
Outer Ring Road	493	1059
G T Karnal Road	313	555
Mathura Road	207	560
Rohtak Road	220	407
Najafgarh Road	204	588
Grant Trunk Road	167	455
Mehrauli Badarpur Road	130	371
National Highway No. 8	138	229
Wazirabad Road	124	324

By writing simple statements in SQL, one can visualize various information like: Accidents on roads, Peak time accidents; pedestrian hit by bus, car, scooter etc; Accidents in the year 2006, 2007, 2008 and 2009 individually with road wise distinction and a lot of other combinations can be worked out. This way a clear picture is visualized with locations of occurrence of accidents.

Hot-spot analysis was done for major roads to see the sections of road where there is clustering of accidents. This tool identifies statistically significant spatial clusters of high values (hot spots) and low values (cold spots). The Hot Spot Analysis tool calculates the Getis-OrdGi statistic (pronounced G-i-star) for each feature in a dataset. The resultant z-scores and p-values tells us where features with either high or low values cluster spatially. This tool works by looking at each feature within the context of its neighboring features. A feature with a high value is interesting but may not be a statistically significant hot spot. To be a statistically significant hot spot, a feature will have a high value and be surrounded by other features with high values as well. The local sum for a feature and its neighbors is compared proportionally to the sum of all features; when the local sum is very different from the expected local sum, and that difference is too large to be the result of random chance, a statistically significant z-score results. It creates a new Output Feature Class with a z-score and p-value for each feature in the Input feature class. A high z-score and small p-value for a feature indicates a spatial clustering of high values. A low negative z-score and small p-value indicates a spatial clustering of low values. The higher (or lower) the z-score shows the more intense the clustering. A z-score near zero indicates no apparent spatial clustering.

Density map of pedestrian accidents in Delhi in four years 2006-09 was created and is shown in the following map. It is clear from the map that density of pedestrian accidents is higher in North Delhi, near ISBT.



Density map for pedestrian accidents in Delhi, 2006-2009

Summary of the analysis

Most of the pedestrians' fatalities involve only one pedestrian. More than two pedestrians involved in road traffic fatalities are in very few cases.

- Pedestrians contribute almost 50% to the total road crash fatalities.
- The type of impacting vehicle has not been reported in several pedestrian fatalities.
- Although very few HCVs are present in the traffic stream still they contribute about 20-30% pedestrians' fatalities. And the other vehicles contribute in pedestrians' road traffic fatalities as - LCVs: 5-8% fatalities. Cars: 9-12% fatalities, Motorized two wheelers: 6-8% fatalities, Motorized three wheelers: 1-2% fatalities.
- It can be inferred from the data that month of the year or weather has no role in the pedestrians' road fatalities in Delhi.
- The pattern of pedestrians' fatalities is quite uniform throughout the day. Though at different times of the day pedestrian volume highly varies. Thus we can conclude that pedestrians' road fatality rates are largely unaffected by pedestrian volume on the road. Even when pedestrians are very sparse on the roads, the pedestrian fatalities are significant.
- The geographic distribution of pedestrian victims highlights the widespread insecurity people experience in Delhi when walking. Fatal crash density is higher near ISBT in Delhi, where population density is also high. To reduce the risk some resources should be dedicated specifically to pedestrian safety. Modifying the urban environment according to pedestrian needs would have many health benefits other than injury prevention that would be related either to increased physical activity or reduced pollution.

Excerpt from the draft (2012) "Summary Report of Pedestrian Fatality Data: Delhi India: 2001 to 2009". Shalini Rankavat, Marya Khatoon and Geetam Tiwari.



News

Motorcycle Antilock Brakes

ARLINGTON, VA — Riding a motorcycle is safer when the bike is equipped with antilock brakes, the Insurance Institute for Highway Safety explains in a new consumer brochure.

“Motorcycle ABS: Why you want to ride with it” explains what antilock braking systems (ABS) do, how they work, and the key research on their safety benefits. The pamphlet, intended for distribution at rider training events and other venues, is meant to encourage riders shopping for new bikes to choose models equipped with the technology. Antilocks are standard on some motorcycles and are available as an option on many more.

“Research shows that motorcycle antilocks dramatically cut the risk of a deadly crash,” says Institute president Adrian Lund. “We want riders to understand how this technology works so they can make an informed choice.”

Braking isn't as simple on a motorcycle as it is behind the wheel of a car. Most bikes have separate brake controls for the front and rear wheels, and either wheel can lock up during hard braking. On a car, a lockup might result in a skid. On a motorcycle, it can mean a loss of balance and a potentially deadly fall.

With ABS, a rider can brake fully without fear of locking up. The system automatically reduces brake pressure when a lockup is about to occur and increases it again after traction is restored. ABS works by constantly measuring wheel speed, but it intervenes to adjust brake pressure only if it detects that a wheel is about to stop rotating. A rider shouldn't notice it at all during normal, nonemergency braking.

Motorcycles equipped with antilock brakes have a 37 percent lower rate of fatal crashes than the same models without antilocks, Institute researchers have found. The Institute's affiliate, the Highway Loss Data Institute, has reported that collision insurance claims are filed 22 percent less frequently for motorcycles with antilocks than for those without it.

The technology benefits riders of all abilities. Even the most skilled rider may be forced to brake hard when cut off or faced with another emergency. Road surfaces can be unexpectedly sandy or more slippery than they look. A test track study by the Austrian Road Safety Board found that both new and experienced riders stop more quickly with ABS than without. The U.S. National Highway Traffic Safety Administration found that stopping distances improve with ABS on wet and dry surfaces alike.

More than 4,000 people died in motorcycle crashes in 2009. Riding a motorcycle is inherently more dangerous than riding in a car because a bike is less stable and less visible to other drivers. Moreover, it lacks the protection of an enclosed vehicle. Antilocks can go a long way toward preventing crashes. When a crash does occur, a helmet is the most effective protection.



The honorary doctors for 2012 have now been appointed at Chalmers. Leif Johnsson was selected for his work to encourage the interest of youth in technology and the natural sciences, to promote education and strengthen the role of the engineer in society. Geetam Tiwari was selected for her research on transport, contributing to a more sustainable transport system in Indian Municipalities. Peter Catto was selected for his research in plasma physics, which has a major impact on the development of fusion power.

Professor Geetam Tiwari was appointed honorary doctor for her visionary research and socially beneficial research on transport. She and her research group have contributed to enhanced knowledge on urban traffic patterns of various vehicles, public health effects in the urban environment and the relationship between the municipal infrastructure and traffic safety. Their research has led to concrete measures, such as the introduction of a Bus Rapid Transit System in Delhi, and guidelines for the design of highways and streets in urban environments. This, in turn, has resulted in improved accessibility and traffic safety, as well as fewer emissions of greenhouse gases and less pollution in general.

Geetam Tiwari and members of her research group Transport Research and Injury Prevention Programme have been collaborating for many years with Chalmers and the University of Gothenburg, which resulted in a collaborative agreement this year. Geetam Tiwari has been a Visiting Professor at Chalmers, funded by the Adlerbertska Foundation. She heads the WHO Collaboration Centre in India.



Professor Dinesh Mohan is one of the world's leading experts on traffic safety issues and human tolerance to injury. His work has significantly advanced motorcycle helmet design, pedestrian and bicyclist safety and child restraint regulations, and helped develop safer ways for various modes of transportation to safely share the roadways. He was one of the four recipients honored with the Distinguished Career Awards at the Alumni Weekend on 1st June 2012 by the University of Delaware. Alumni were selected for recognition based on achievement, impact, uniqueness and interest.

In 1997, he helped establish and coordinated until 2010 the Transportation Research and Injury Prevention Programme (TRIPP), which presents a replicable model for creative interaction and cross-divisions problem solving for research, academia and other groups in cities worldwide.

Among his many honors are the 2001 Bertil Aldman Award for outstanding contribution to the subject of impact biomechanics, International Research Council on Biomechanics of Impacts; and the 2000 International Distinguished Career Award from the American Public Health Association.

Establishment funds have been received from

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Asian Institute of Transport Development
Tata Motors, India

Volvo Research and Educational Foundations (VREF), Sweden

Endowments for perpetual Chairs

CONFERR, India: TRIPP Chair for Transportation Planning
Ministry of Urban Development India: MoUD Chair for Urban Transport & Traffic Planning
VREF: Volvo Chair for Transportation Planning for Control of Accident and Pollution

Transportation Research and Injury Prevention Programme

Room MS 815 (Main Building)

Indian Institute of Technology

Hauz Khas, New Delhi 110016, India

Phone: 91-11-26596361, 26858703

Fax: 91-11-26858703, 26851169

Email: ird8541@cbme.iitd.ernet.in

<http://tripp.iitd.ernet.in>



Excerpts from two 2011 publications: A TRIPP BULLETIN INSERT

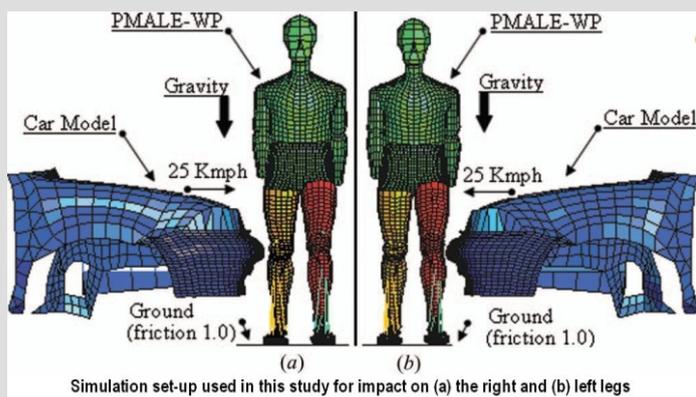
Effect of Muscle Contraction in High-Speed Car-Pedestrian Impact: Simulations for Walking Pedestrian

Pedestrians constitute 65% of the 1.17million people killed annually in road traffic accidents worldwide(World Bank Group, 2007). Epidemiological studies on pedestrian victims have indicated that together with the head, lower extremities are the most frequently injured body region (Chidester and Isenberg, 2001; Mizuno, 2003). Pedestrian Crash Data Study (PCDS) (Chidester and Isenberg, 2001) reports that passenger cars have the biggest share in vehicle-pedestrian accidents. Furthermore, the front bumper was the major source of injury to the lower extremity when injuries were caused by a vehicle structure (Mizuno, 2003). This has posed a challenge for vehicle designers to design pedestrian-friendly car front structures. To devise effective pedestrian protection systems, it is essential to understand the injury mechanism.

So far, the lower limb injury mechanism in car-pedestrian crashes has been studied through tests on human cadaver specimens (Kajzer et al., 1990, 1993, 1997, 1999; Kerrigan, 2003, Bhalla et al., 2005) and simulations using validated passive FE models (Schuster et al., 2000; Maeno and Hasegawa, 2001; Takahashi and Kikuchi, 2001; Nagasaka et al., 2003; Chawla et al., 2004; Soni et al., 2007). However, the major shortcoming in these existing experimental and computational studies is that they do not account for muscle action. Therefore, effects of precrash muscle contraction on the response of lower limbs in car-pedestrian crashes remained unclear.

Soni et al., (2007) have investigated the probable outcome of muscle contraction using a lower limb (single leg) finite-element (FE) model with active muscles (A-LEMS). More recently, Soni et al. (2009a, 2009b) have extended the single leg model A-LEMS to a full body pedestrian model with active lower extremities (PMALE) and studied the effects of muscle contraction on the response of lower extremity for a symmetrically standing pedestrian (with legs in side-by-side stance) in full-scale car-pedestrian impact. However, PCDS reported that prior to the crash, only 4%pedestrians were in the stationary standing posture whereas 55% were walking.

This study extends our earlier studies to investigate the effect of muscle contraction on the response of lower limb for pedestrian walking posture in full-scale car-pedestrian lateral impact at low speed. The PMALE, which was configured in the standing posture, has been repositioned in the walking posture. The real-world car-pedestrian lateral impact has then been simulated using the PMALE configured in the walking posture (PMALE-WP) and front structures of a validated car FE model. Two impact configurations, i.e. impact on the right and left legs of PMALE-WP, have been simulated. Two sets of simulations, i.e. with deactivated and activated muscles (including reflex action), mimicking an unaware walking pedestrian have been performed for both the impact configurations. Strains in knee ligaments and Von Mises stresses in bones for two levels of muscle activation have then been compared to assess the effect of muscle contraction.



Data analysis

Two nodes at both femur and tibia have been selected to obtain the nodal time history in simulations. Relative movements of selected nodes are then used to calculate relative tibia displacements and knee joint angles. Sign conventions used here are as per the SAE standards. An element elimination approach has been enabled to simulate the failure in the ligaments and bones. Knee kinematics, strain time history of each knee ligament and Von Mises stress contours in bones of the impacted leg of PMALE-WP have been recorded from the simulations. The response in cadaveric and reflex conditions has then been compared to determine the role of muscle contraction.

Conclusion

In this study, effects of muscle contraction on the response of lower limb for pedestrian walking posture in low speed lateral impacts have been studied. The full body model with active lower extremities i.e. PMALE, which was configured in a standing posture, has been repositioned in the walking posture (PMALE-WP). The real-world car-pedestrian lateral impact has been simulated using the PMALE-WP and front structures of a validated car FE model. Two impact configurations, i.e. impact on the right and left legs, have been simulated. For each impact configuration, two sets of simulations, i.e. with deactivated and activated muscles (including reflex action), mimicking an unaware walking pedestrian have been performed. Differences in response between a cadaver and an unaware pedestrian have been studied. To assess the effect of muscle activation, knee kinematics, strains in knee ligaments and Von Mises stresses in bones have been compared. Finally, the following conclusions can be drawn from the present study.

- In both impact configurations, peak strains in the knee ligaments were lower in the reflex condition (with active muscles) when compared with the cadaveric condition. This supports our previous findings that the risk of ligament failure in real-life crashes is more likely to be lower than that predicted through cadaver tests or simulations.
- It was found that strain in ACL was higher than PCL strain in case of impact on the leg in heel strike phase (i.e., the leading leg), whereas, in case of impact on the leg in the terminal stance phase (i.e., the trailing leg), this pattern of higher strain reversed, which means that the strain in PCL was higher than ACL strain. This leads to the conclusion that knee ligament failure is posture specific.
- In all four simulations, MCL has failed, whereas LCL remained nearly unstrained. This implies that in lateral impacts, MCL could be considered as the most vulnerable and LCL as the safest ligament.
- In all the four simulations, tibia and fibula were fractured. This suggests that active muscles may not have significant effect on bone fracture in high-speed car-pedestrian crashes.
- It is observed that bone fracture unloads the knee joint and hence reduces the chances of ligament failure.

It must, however, be noted that the muscle parameters used in this study represent an average male. Muscle strength (maximum force capacity combining fatigue level) varies from one individual to another and also with age and gender. However, these effects are not quantified and studies need to be conducted to quantify the effect of these parameters.

Experts from: A Soni, A Chawla, S Mukherjee, R Malhotra (2011). "Effect of Muscle Contraction In High Speed Car-Pedestrian Impact - Simulations for Walking Posture" *International Journal of Vehicle Safety, Vol 5, NO. 2, pp 101-116.*



Accessibility and Safety Indicators for All Road Users: Case Study Delhi BRT

Travel is a derived demand, i.e. people travel in order to access employment, education, health facilities, recreational and commercial activities. Distances travelled and choice of mode for travel is dictated by the socio-economic profile of the users and availability of mode choice. In Indian cities, a large proportion of population lives in slums, for example in Mumbai 54.1% of the population lives in slums, Kolkata 32.5% and in Delhi 18.7%. This group of people cannot afford personal motorized vehicles (cars and two-wheelers) for transportation and even subsidized bus systems are too expensive for them for daily commute (Tiwari, 1999). Their transportation needs are thus dependent on non-motorized transport (NMT) which includes walking or cycling. As such, even in the megacities of India (city population more than 8 million), 30% of the trips are made by NMT, 50% by public transport (PT) both formal and informal bus systems and tempos and rest are by Personal Motorized Vehicles (PMVs), i.e. cars and motorized two wheelers (MTWs).

The traditional approach of evaluating transport projects measures benefits for PMV users only. As discussed the "users" of the transport system are a heterogeneous mix of people of different socio-economic classes, with differing needs of travel. These differential concerns make the task of assessing the feasibility of a project more complex – some users may benefit, some may not, and some may not be affected at all. Also, there may be a category of non-users of the project – people who are not the target group but may experience an indirect impact of the project. The evaluation of a transport infrastructure improvement project thus needs to assess benefits for different types of users and not only in terms of improved performance of the vehicular system, but much wider on the impact of the well being of all the people affected by the investment.

The paper develops new indicators to measure the impacts of a project on accessibility and safety of different types of users. The paper compares the difference in results using traditional and new indicators. Both the methodologies are applied to evaluate the impact of Bus Rapid Transit (BRT) corridor in Delhi, an open BRT system operational since April 2008 from Ambedkar Nagar to Moolchand flyover on a stretch of 5.8 km. The corridor is supported with footpaths and bicycle lanes along with other supportive facilities like pedestrian signalized crossings, spaces for street vendors, parking facilities for bicycles as well as three wheeled taxis to provide safe commute to both NMT and bus users.

The focus of this study is to develop indicators for both accessibility and safety that takes into account the effect of a project on different types of users of the system.

The development of new indicators is framed around the conceptual model of transport systems based on traffic, transport and travel market analogies (Godefrooij and Snoeren, 2010).

A transport infrastructure improvement project has impact on the interaction between modes, speed and flows of different types of users. Along with this a transport project can also result in detours for some of the users resulting in the change in distance to be travelled and comfort levels. The way different types of users move to access desired locations is termed the traffic market.

Previous studies have shown that the improvement in infrastructure for a mode results in modal shifts (Cascetta et al., 2011; Vedagiri and Arasan, 2009). Transport market is related to the mode choice of people that changes with the change in speed, cost, safety and comfort aspects of using each of the modes. It is a long term impact of a transport project measured as the modal change which takes place as a result of the change in traffic market because of the implementation of project.

Both traffic and transport market have an impact on the action of different type of users and hence on the accessibility options to various employment and other opportunities.

The proposed indicators can be used to measure the impacts on the sustainable modes of transportation-pedestrians, bicyclists and public

transport users. This may help in achieving the long term policy goals of increasing the share of these modes.

The impact of implementation of BRT corridor in Delhi has been evaluated using traditional and new indicators of accessibility and safety. As per the analysis using traditional indicators, the speed of PMV has reduced by 12.5% and of buses has increased by 25%. Since PMV constitutes about 75% of the total vehicles on road the analysis shows that the implementation of BRT corridor has resulted in increased cost to society. However, analysis using the new indicators shows that the total travel time saving by all the users is 19%. The traditional indicators lack this level of analysis. With the increased speed of buses and cycles more destinations are accessible within the same travel time. Also, the catchment area of destinations has increased considerably. The new indicators also shows that accessibility options to opportunities has increased by 120% for bicycle users and 730% for people who walk to access bus on the BRT corridor and to reach their final destination from the bus corridor. Thus from the analysis it can be said that the Delhi-BRT corridor has benefited especially the NMT and PT users.

The traditional indicators of safety quantify the increase in overall safety parameter of the BRT corridor. However, the new indicator of safety lays emphasis on the changing interaction between different modes and identifies the victim and impacting vehicles. Also, the indicator measures the change in safety parameters for different mode users independent of the kilometers travelled. As per the analysis using new indicators, the risk to cyclists has reduced to zero and the pedestrians who were more affected by the bus have become safer.

The evaluation using new indicators is thus able to capture the change in accessibility and safety parameter especially for the captive road users of society for whom the mode choice is limited. The indicators are able to measure the change in radius of action as well as in the number of opportunities. The new indicator thus could identify the true beneficiaries of the system by evaluating impacts on different types of users of the system. Moreover, the approach helps decision makers and planners to select the measures that are in favor of promoting sustainable transport system.

The studies done so far, evaluate the impacts of transportation infrastructure projects either on a single user of the system or use traditional approaches that measure benefits such as speed, queue length of vehicles and the investments made in the project such as its cost. The conventional approach of evaluating transport projects shows reduced car speeds, longer wait time and queue lengths at the traffic intersections for cars thereby suggesting lower level of service achieved. However, using a new set of indicators, it was possible to show that the Delhi-BRT corridor has had some major positive impacts across a range of road users. The major difference in outcome is that the new indicators utilize a detailed analysis of the occupancy and utility factor of all types of road users including cars, buses as well as bicycles and pedestrians, so are sensitive to a wider set of potential beneficiaries.

The new indicators of safety rely upon knowledge of the interaction between different modes and hence incorporate the change in risk exposure to different mode users and risk imposed by a mode on other modes. This knowledge also gave us to the number of vulnerable road users affected by the project. The new indicators also show the impact on both travel and transport market and show changes in the competitiveness of different modes. As per the traffic indicators bus and bicycle commuters have got relief from traffic congestion. Using new indicators it is found that accessibility to different activity centers increased by 120% if only cycles are used, 100% if cycles are used to access bus service on the corridor and by 730% if people walk to access bus service. This level of information and evaluation was not possible with the use of the traditional indicators.

By emphasizing the types of users of a transport project the new indicators can complement the narrower perspective of the traditional approaches and provide a complete evaluation of a transportation project.

Excerpts from: Tiwari, G. and Jain, D(2012). "Accessibility and Safety Indicators for All Road Users: Case Study Delhi BRT" *Journal of Transport Geography*, 22, 87-95.

