TRIPP BULLETIN
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TRANSPORTATION RESEARCH & INJURY PREVENTION PROGRAMME
INDIAN INSTITUTE OF TECHNOLOGY DELHI

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Kumar Neeraj Jha (2013). ISBN:978-94-007-6255-8, Springer, The Netherlands

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A large-capacity foldable transport container
Chawla, A & Mukherjee, S. (2012). Number Ep2125577, Assignee - Indian Institute Of Technology Delhi (Hauz Khas, New Delhi, IN) Simpri Investments Limited (P.O. Box 3476 GPO, Hong Kong, CN)

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Mohan D. *In VREF: 10 Years with the FUT Programme, 22-31 Goteborg: The Volvo Research and Educational Foundations, VREF.*

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Research & Consultancy Projects

Sustainable Urban Transport in Less Motorised Countries: Research and Training
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Estimation of Emissions and Fuel Consumption of in-use Vehicles in Different Driving Conditions.
Sponsor *Petroleum Conservation Research Association*
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Promoting Low Carbon Transport in India
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Road Safety Political Mapping in India
Sponsor *Global Road Safety Partnership, IFRC, Geneva ,Switzerland*
Team *G. Tiwari and G. Agrawal*

Development of Toolkit on Road Safety Audits
Sponsor *Institute of Urban Transport (India)*
Team *G Tiwari, D. Mohan and K .R. Rao*

Development of Toolkit on Public Transport and Accessibility
Sponsor *Institute of Urban Transport (India)*
Team *G Tiwari, D. Mohan and* K Ramachandra Rao

Study on Community Design for Traffic Safety
Sponsor *The International Association of Traffic and Safety Sciences (Japan)*
Team *D. Mohan, G. Tiwari and S. Mukherjee*

Driver Behavior Characteristics in India
Sponsor *Renault Nissan Technology & Business Centre India Pvt. Ltd.*
Team *D.Mohan, G.Tiwari, S. Mukherjee and S. Banerjee*

Smartphone Application Acceptability and its Impact on Driving Behaviour of Drivers in Delhi
Sponsor *Renault Nissan Technology & Business Centre India Pvt Ltd.*
Team *D.Mohan and G. Tiwari*

Public Health Impacts in Urban Environments of Greenhouse Gas Emissions Reduction Strategies - PURGE
Sponsor *European Union*
Team *D. Mohan and G. Tiwari*

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.

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How bad is the air quality in the Indian cities?

The World Health Organization (WHO) studied publicly available air quality data from 1100 cities across the world and listed 27 cities in India among the top 100 cities with the worst air quality in the world, with Ludhiana, Kanpur, Delhi, and Lucknow among the top 10 cities. In 2011, the Ministry of Environment and Forests (MoEF) published the results of a source apportionment study for six cities in India (Bangalore, Chennai, Delhi, Kanpur, Mumbai, and Pune). Air pollution is a complex mixture of pollutants with sources ranging from fossil fuel burning in transportation, power generation, industries, and domestic sectors. In all the cities, transport remains an important source of ambient air pollution from direct vehicle exhaust emissions and indirect resuspension of dust due to constant movement of vehicles on the road.

What do we know about vehicle ownership and usage in India?

According to the Ministry of Road Transport and Highways, the total registered vehicle fleet in India is 112 million in 2010.

While the total vehicle numbers have significantly increased between 1990 and 2010, the per capita rate of ownership of private cars in India is still lower than those observed in the European Nations, the United States, and Canada. As incomes rise, car ownership will increase proportionately and consequently the pollution problems in the cities. We estimate that the total fleet will increase four to five folds by 2030, based on the current (high business as usual) scenario.

The demand for transportation services outstrips the supply of options in most parts of the country. The main reason for this is economics - people have to make do with available transport modes - be it a growing middle class family, who still use a two-wheeler or travelers who hitch a ride on any available locomotive contraption to go between villages. All the vehicles (motorized and non-motorized) are utilized for multiple purposes, like passenger and freight transport, under varying loading conditions, in all terrains from high altitude Kashmir to the plains of Tamilnadu and Kerala.

Motorized two-wheelers like scooters, small capacity motorcycles and mopeds are very popular due to their cost, fuel efficiency and ease of use in congested traffic. Fuel in India is not inexpensive, and hence the fuel economy and convenience of negotiating traffic are major advantages of using motorized two wheelers. While rules regarding the number of people traveling on them exist - especially in cities - they are often ignored.

Negotiating tiny by-lanes and weaving through traffic is the main advantage of the three-wheeler light-duty passenger vehicles in most of the Indian cities. These form an integral part of passengers and freight movement. Three wheelers are also used as the para-transit systems in areas that are served by metros (in cities like Mumbai, Kolkata, Delhi, and Chennai). They are a popular mode of mass transport for school children. Smaller towns usually operate six-seater vehicles that provide services similar to mini-buses (by plying on dominant routes).

Trucks are the main mode of freight transport between cities, especially from the ports, which may be less than optimal compared to the railways. The large heavy duty container trucks (more than 20 tons) are now available in India, servicing from the ports to the cities, which was largely serviced by the 12-16 ton trucks in the past. Most of the cities have a moratorium on the heavy duty vehicles from entering the city limits between 6 AM and 9 PM, which was introduce to reduce the possible congestion on the roads and to reduce exposure to harmful diesel fumes during the daytime. This also led to a higher proportion of the light-duty trucks and three-wheelers catering for freight movement during the daytime.

The towns and cities in the Himalayas are entirely serviced by trucks - for every product including fuel. The trucks running these routes in the spring, summer, and fall months are often driven in the lowest gear under full load conditions, which tend to exacerbate the local ambient pollution levels in these areas.

An often overlooked mode of transportation, especially in rural areas, is that provided by tractors. These heavy duty vehicles are able to cover regions with mud roads and with a wagon hitched at the back have enough horse power to haul significant loads. They are used to also haul non-agricultural products such as bricks from brick kilns (located most often in fields), mud, gravel and sand for construction, agricultural waste etc.

Non-motorized transport (NMT) is an invisible fleet category in India - these may include hand carts, cycles, and horse/camel/bullock carts. In urban and rural areas freight in the form of vegetables, electronics, and construction material, is transported by NMT. These trip lengths are on an average shorter than those using motorized transport. Although they do not release emissions themselves, they do share road space with other transport categories and we should not neglect their contribution to the movement of goods and people and overall sustainable development of urban transport systems.

How are transport, air pollution, and health linked?

Air pollution disproportionately affects those most vulnerable with compromised or still developing immune systems the sick, the elderly and children. In India, those with means travel in cars and use air conditioning indoors, which to a small extent insulates them from chronic exposure to the pollutants. However, most people are directly exposed to pollution on road corridors or those living along roads bear the brunt of the air pollution. That said, several studies have looked at this issue based on extensive epidemiological and cohort studies to better understand the relationships between ambient pollution by various pollutants and different health end points. A study conducted by the University of California (Berkeley) in Delhi, suggested that the on-road exposure to air pollution, for

the passengers traveling in a three wheeler, is at least 1.5 times worse than the average ambient concentrations.

The pollutants critical to health are sulfur dioxide (SO2), nitrogen oxides (NOx), particulate matter (PM), carbon monoxide (CO), volatile organic compounds (VOCs), and various trace metals. The transport sector is a major contributor to total NOx and CO emissions and the diesel combustion in cars, buses, and trucks contributes to SO2 and PM emissions.

The global burden of disease (GBD) study quantified the trends of more than 200 causes of deaths for the period of 1990-2010 and listed outdoor air pollution among the top 10 causes of deaths for India (published in the Lancet series, December 2012). For India, total premature mortality due to outdoor particulate matter (PM) pollution is estimated at 627,000 with most of these impacts felt in the cities. This GBD assessment utilized a combination of ground measurements (where available) from the cities and substituted the remaining urban and rural area with data retrieved from satellite measurements. Most notable of the health impacts resulting in premature deaths and those linked to ambient air pollution include chronic obstructive pulmonary disease, lower respiratory infections, cerebrovascular disease, ischemic heart disease, and cancers of trachea, bronchitis, and lung.

The morbidity and mortality burden is particularly costly for the government in terms of work days lost, lost productivity, and loss in terms of gross domestic product. Since, the most health impacts occur within a year or two of exposure, reducing the ambient pollution from sources like transport and industries has an immediate benefit.

What can the public and the governments do to address this problem?

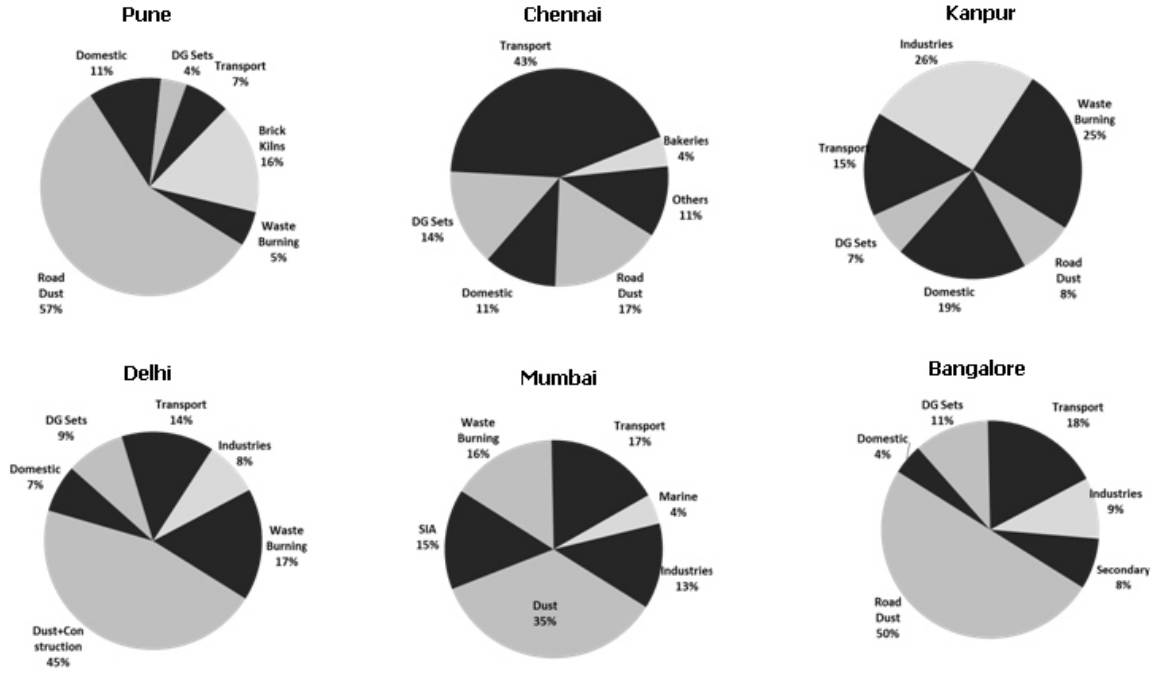
Emissions from the transport sector are a result of multiple factors - including but not limited to, vehicle fuel standards, badly maintained roads and public transport vehicles, lack of transportation options and urban planning, adulterated fuel, aging fleets, and a large freight movement on-road. The health impacts of air pollution from the transport sector are not insignificant and the nature of the issue is that those areas with the most population density are most affected. Unless air pollution is addressed on multiple fronts - science and policy, it will continue to be a matter for grave concern.

There cannot be a silver bullet to address this issue and one cannot have an impact on emissions from transport using only one policy instrument. Policy measures implemented in isolation will not work. For example, improving fuel efficiency standards is important, but enforcing them in select cities does not yield the expected benefits, given the diversity in the vehicle usage in the country. Besides standards, we need programs where roads are well maintained, traffic bottlenecks are eased, vehicles maintenance is promoted, and the available fuel is unadulterated.

Unless behavioral change gets people to use more public and non-motorized transport, pollution in the cities will continue to be a big issue. This will require a concerted and coordinated effort between multiple stakeholders like individuals, industry, and the government. For example, the government needs to provide resources towards public transport to implement policies that fall outside the purview of transport (for instance urban zoning) and industries can provide incentives to employees to spur the use of public transport.

The message is clear: with the growing number of vehicles, we are bound to experience a spike in the pollution levels, regulatory bodies will have to take a quantum leap, especially in terms of managing passenger traffic and freight at all levels urban, regional, and national. They will have to implement radical solutions ranging from technical, social, policy, to economic, within a short time-frame for long-term gains.

Average percent contributions of major sources to particulate pollution



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News

Good, better, best: the city of Copenhagen's bicycle strategy 2011-2025
(Published by the City of Copenhagen. Available from www.kk.dk/cityofcyclists) COPENHAGEN MUST BECOME THE WORLD'S BEST BICYCLE CITY!

"The goal was firmly set by a unanimous city council as an integral part of the vision of Copenhagen as an Environmental Capital. Above par conditions for cycling are also an important element in Copenhagen's goal of having a good city life and making Copenhagen C02 neutral by 2025. Good conditions for cycling are also part of the city's official health policy.
In other words, cycling is not a goal in itself but rather a highly- prioritised political tool for creating a more liveable city. Copenhagen is already a fine bicycle city. Every single morning hundreds of thousands of Copenhageners choose the bicycle as the most natural thing in the world. It is amazing to many foreigners and the source of great interest for journalists, researchers, politicians and urban planners from every corner of the world.
Copenhagen couldn't have achieved this status without a steady and comprehensive effort. Cycling in Denmark has fallen by 30% since 1990. The numbers for Copenhagen, however, head in the opposite direction. The number of kilometres cycled has risen by around 30% since 1998 and the bicycle's modal share for trips to work or educational institutions has risen to over a third in the same period. This makes the bicycle the most popular transport form for commuting in Copenhagen.
The goal of this publication is to highlight, with the help of words, numbers and photos, what is required if Copenhagen is to reach its ambitious goal of increasing the modal share for bicycles. Not to mention making the city more bicycle-friendly. In other words,how we can take Copenhagen to the next level as a bicycle city.From good to better and on to the best in the world.
This bicycle strategy replaces the municipality's former bicycle strategy "Cycle Policy 2002-2012".
Ayfer Baykal, Mayor of Technical and Environmental Administration

Valuing active travel: Including the health benefits of sustainable transport in transportation appraisal frameworks
Corinne Mulley, Rob Tyson, Peter McCue, Chris Rissel, Cameron Munro. *Research in Transportation Business & Management 7 (2013) 27–34*

Sustainable transport investments linked to improving public transport or designed specifically to improve walking and cycling networks (for example, bicycle infrastructure) typically underestimate the contribution of these active travel modes. This is because the investment appraisal mechanism, social cost benefit analysis, lacks an agreed methodology or well defined parameter values for establishing the demand and the associated health benefits and costs of active travel.
Correcting for the acknowledged benefits of walking and cycling (including contributions to achieving physical activity targets and maintaining health) requires an appropriate framework and parameter values to allow these benefits to be captured in a robust and consistent manner. This paper proposes such a framework for the Australian context and a consequent weighted benefit of $1.68 per km (range $1.23–$2.50) for walking and a $1.12 per km (range $0.82–$1.67) for cycling that includes both mortality and morbidity changes resulting from a more active lifestyle. Investigation of the potential health costs associated with motorised travel and reduced physical activity requires further detailed research.

New research adds to the evidence that motorcycle ABS prevents crashes
Status Report, IIHS, May 30, 2013, http://www.iihs.org/externaldata/srdata/docs/sr4804.pdf

Motorcycles with antilock braking systems (ABS) are 31 percent less likely to be involved in fatal crashes than those same motorcycles without ABS, a recent IIHS analysis shows. Meanwhile, a new HLDI study shows a 20 percent reduction in the rate of collision claims with ABS and a 28 percent reduction in the frequency of claims for rider injuries. HLDI analysts also found that ABS had an engine displacement of more than 125 cc will be required to have ABS beginning in 2016… "The data continue to accumulate in support of motorcycle ABS five years after we first reported on its effectiveness," says Adrian Lund, president of both IIHS and HLDI. "We hope NHTSA will agree that it's time to take action to ensure all riders get the benefit of this lifesaving technology."
Collision claim frequency for crash damage to the motorcycle was 20 percent lower for bikes with ABS than for those without the feature. Claims under medical payment (MedPay) insurance, which covers injuries to the motorcyclist, were 28 percent lower, while claims under bodily injury insurance, which covers injuries that at-fault riders cause to other people, including their passengers, were 22 percent lower.

Course Announcement

The Transportation Research and Injury Prevention Programme (TRIPP) at the Indian Institute of Technology Delhi, is organizing an eight day **"International Course on Transportation Planning and Safety"**. The course will be held in New Delhi, India, from 3 - 10 December 2013. The course will have a common component for the first three days, followed by three parallel modules on Traffic Safety, Biomechanics and Crashworthiness and Prehospital Care and Trauma.

Details of the course can be accessed from -http://tripp.iitd.ernet.in

Establishment funds have been received from
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Endowments for perpetual Chairs
CONFER, India: TRIPP Chair for Transportation Planning
Ford Motor Co., USA: Ford Chair for Biomechanics and Transportation Safety
Ministry of Urban Development India: MoUD Chair for Urban Transport & Traffic Planning
MoUD Chair for Urban Transport and Environment
VREF: Volvo Chair for Transportation Planning for Control of Accident and Pollution

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Excerpts from two publications: A TRIPP BULLETIN INSERT

Safety Incentive and Penalty Provisions in Indian Construction Projects and their Impact on Safety Performance

Construction safety is of paramount importance in any construction project. Safety performance in a project is just as much a measure of the success of that project as are measures of time, quality and cost. The frequency of occurrence of disabling injuries suffered by construction workers is roughly twice the frequency of such incidents in other industries and the death rate is roughly thrice that in other industries (Hinze & Applegate, 1991). In India,the construction sector employs around 33 million people (Jha, 2011); so the issue of safety assumes enormous importance. The objective of safety I/P schemes is to ensure the safe completion of construction projects by penalising the contractor for every unsafe act or condition and awarding incentives for excellent safety performance. Incentive/penalty provisions are primarily used to align the contractor's motivation with the owner's project objectives so that the overall performance can be improved.

It can be observed that very few researchers have tried to study the impact of I/P provisions on the safety of construction projects. Further, the results are found to be quite contradictory when it comes to the positive impact of safety I/P provisions on project safety. There are many ways in which incentives can be implemented,though little is known about the most effective way of doing so. Incentivisation measures have been launched with success in the USA, UK, China and Australia (Chan & Chan, 2010), but no systematic research has been carried out to analyse the applicability of these provisions in Indian construction projects. The objectives of the present study are: (1) to examine the effectiveness of safety I/P provisions in improving the safety performance of construction projects and (2) to identify and evaluate the different attributes which need the attention of both the client and contractor for the successful formulation and implementation of safety I/P provisions.

In pursuance of the first objective, the authors of the present study collected statistics on the 'average number of persons employed', 'million man-hours worked', reportable lost time injuries', 'man-days lost due to injuries', 'frequency rate', 'severity rate' and 'incidence rate' from 32 ongoing building and factory onstruction projects of a leading Indian contractor. The contractor is not only a large engineering conglomerate, but also has substantial presence in the overseas market. Out of the 32 projects, the client organisations had made provisions for safety I/P in the contracts for only 14 projects, leaving the rest without any such provisions in the contract. The involvement of the same contractor in all these projects ensures that the other factors that affect the safety performance at construction sites would remain more or less the same in all the projects. Although the site conditions and technical difficulties varied in the studied projects, it was assumed that their comparison would give a fair idea about the effectiveness of safety I/P provisions in improving safety performance. Analysis of variance (ANOVA) was performed at significance level, a¼0.05 to check whether there is any significant difference among the safety performances in the two sets of projects. Safety indices (frequency rate, severity rate and incidence rate) were calculated using the safety statistics collected from various sites using equations in accordance with IS: 3786-(1983). In pursuance of the second objective, a survey based on structured interviews of highly experienced Indian construction professionals through a preliminary questionnaire and various research papers was conducted. A total of 25 important attributes affecting the safety incentive/penalty provisions of projects was identified. Based on these important attributes, a final questionnaire was prepared and distributed among Indian construction professionals with more than 10 years of experience and working on various projects wherein safety I/P provisions were being used. Out of the 120 questionnaires distributed among experienced professionals representing 14 big reputed companies, a total of 72 responses (a response rate of 60%) were collected.

Factor analysis is a powerful method of statistical analysis that aims at providing greater insight into relationships among numerous correlated but seemingly unrelated variables in terms of relatively few underlying factor variants (Dillon & Goldstein, 1984;Overall & Klett, 1972). Factor analysis has been used in construction management by various researchers for different purposes. The examples of factor analyses include factor analysis of attributes affecting success and failure of projects (Iyer & Jha, 2005), factor analysis of policy, process, personnel and incentive aspects, which may help project managers manage the safety of construction sites (Teo et al., 2005), factor analysis of attributes facilitating relational contracting and factor analysis of attributes facilitating the building of integrated project teams (Rahman & Kumaraswamy, 2008). Factor analysis performed on all the response sets has yielded some significant interpretations, while the variables emerging from various factors under isolated response sets of clients, consultants and contractors have been found to be jumbled and not leading to any significant interpretation. Since the factors extracted by using principle component analysis are orthogonal and contain a large number of overlapping attributes across various factors, they are not amenable to interpretation. Varimax rotation was employed to make the factors amenable to interpretation. The total number of factors was fixed on the basis of both eigen values (>1) and scree plot.

Use of safety incentive/penalty provisions in a construction project results in a lesser number of accidents and better safety performance when compared to project with no I/P provisions, but a better outcome can be achieved if the I/P provisions are formulated and implemented in a proper manner. Safety performance can be improved by distributing I/P in suitable forms and in the right manner, providing proper training to construction workers, giving special consideration to specialised tasks and risky situations, acknowledging the role of safety committee and subcontractors, and maintaining a good safety equipment inventory. It is necessary for a client to incorporate a detailed safety incentives/penalty scheme which covers penalty charges on most of the unsafe acts or conditions ignored or condoned by the contractor. Also, a client should include incentives in the form of various awards and recognition in order to motivate the development of a safe work culture at construction sites. These awards should be holistically based on safe behaviour and team spirit rather than on mere non-incidence of injuries/accidents only. A contractor needs to work out a complete and detailed safety policy and implement it if he wants to avoid monetary penalties on unsafe acts or conditions. It is very important to develop the right attitude towards safety in construction workers. A separate safety committee with the requisite expertise and experience should be formed to prepare and implement the safety program at the site. Proper accident or disaster management plans should be developed to devise the right methods to respond to any accident or life-threatening disaster.

The prime contractor should select sub-contractor with utmost care. Regular safety workshops and training should be organised, preferably in the native language of workers. Use of PPEs and other safety tools and equipments should be made compulsory while carrying out risky tasks. Although the present study is based on the perceptions of Indian construction professionals and data on safety provisions/norms/practices from Indian construction projects only, it is believed that the findings of this research would be equally applicable to construction projects elsewhere. The factor analysis does not indicate the relative significance of different factors in influencing the success of the projects with safety incentive/penalty provisions. This leaves scope for future research to evaluate these factors. In addition, the finding that inclusion of safety incentive/penalty helps in improving the safety performance can be validated further by analysing data on safety provisions/norms/practices from construction projects outside India.

Excerpts from: Abid Hasan and Kumar Neeraj Jha (2013). "Safety incentive and penalty provisions in Indian construction projects and their impact on safety performance", *International Journal of Injury Control and Safety Promotion, Vol. 20, No. 1, 3-12.*

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A Megacity in a Changing Climate: The Case of Kolkata

The Intergovernmental Panel on Climate Change (IPCC), in its overview of global trends of extreme weather events up to 2006, notes that the frequency of heavy precipitation events has increased over most land areas (IPCC AR4 2007). Historical evidence highlights the dangers associated with such intense precipitation events in developing countries. Flood-related deaths increased steadily from 17,000 in the 1960s to more than 58,000 in the 1990s in developing countries (EM-DAT 2010). Floods affected billions of people who were injured,made homeless, or forced to seek emergency assistance. Recent examples of devastating extreme precipitation impacts in developing countries include the following: floods in Pakistan (1,600 people died and 14 million people were displaced in July 2010), India (24 died and 1.1 million people were displaced in July 2010), China (12 died and 300,000 people were displaced in Hubei, Sichuan, and Shananxi provinces inMay 2010; 60 died and 4.7 million people were displaced in southern China in July 2010), and Mozambique (35 died and 130,000 people were displaced in February 2010); tropical cyclone Nargis in Myanmar (100,000 people died and the livelihoods of 1.5 million people were affected in May 2008); and cyclone Sidr in Bangladesh (243 people died and the livelihoods of 7 million people were affected in November 2007). The impacts are particularly disastrous when extreme weather strikes densely populated urban centers.

This study of Kolkata is based on the urban agglomeration, the Kolkata Metropolitan Area (KMA), as defined in the Vision 2025 document (KMPC 2004). However, given the paucity of available data for the entire area for all aspects of the study, some of the more detailed analysis is confined to the Kolkata Municipal Corporation (KMC), the more urbanized heart of the KMA.

The drainage and sewer network in the KMA is sparse and not commensurate with its area of 1,851 km^2. Where the network exists, it is mostly comprised of a century-old drainage and sewer system. The drainage system is divided into 25 drainage basins (catchment areas), and the entire metropolitan area is divided into 20 sewer zones (zones for the sewer network). Of the 41 municipal towns in the KMA, the piped sewer network is confined mainly to the KMC, Panihati, Titagarh, Bhatpara, and Kalyani on the East Bank and Howrah MC, Bally, Serampore, Chandannagar, and Hooghly-Chinsurah on the West Bank. However, it is intended that all municipal towns will be connected with sewer lines by 2025.

The KMC, which covers 185 km2 and is divided into 141 wards, is the core component of the KMA (KMC 2010). As per the 2001 Census, the population of the KMC is 4.6 million people. The average population density of the KMC is 24,760 persons per sq. km. The KMC accounts for 31 % of the KMA's population, with only 10 % of its area. More than a third of the KMC's population lives in slums. Within the KMA, the KMC lies along the tidal reaches of the Hooghly River, which were once mostly a wetland area. The slope and the transformation of the marshy land into an urban area have made drainage difficult. The elevation of the KMC area ranges from 1.5 to 9.0 m above MSL with an average elevation of 6 m above MSL.

The sewer network in the KMC covers 55 % of the total area. The KMC is divided into nine major drainage basins, each with an independent sewer network and a terminal pumping station. Three of the basins drain into the Hooghly River on the west and six drain into the Kulti system in the east. Eleven sluice gates on the Hooghly River prevent tidal ingress into the sewer system during heavy storms and high tide. The existing sewer network covers a length of 1,610 km and the length of open drains is about 950 km. However, the central part of the KMC sewer network system (town system) is almost 140 years old. Heavy siltation and inadequate maintenance of the channel outfall structures have resulted in a significant reduction in the hydraulic capacity of the KMC sewer system (Kolkata Municipal Corporation 2007).

Flooding in Kolkata is an annual feature during the monsoons. Any past incidence of high intensity rainfall synchronized with high tide in the Hooghly River has almost always resulted in water-logging in Kolkata. Yet there has been no mass exodus from Kolkata during temporary floods, possibly because the magnitude of most such floods has not been very large or long lasting, and the population has learned to adapt to floods by taking precautions to protect critical assets and prepare for health risks. However, the situation may change if flooding becomes more severe as a result of climate change. The causes of flooding in the KMC and the KMA can be categorized as follows:

* *Natural factors*: The area's flat topography, low relief, and natural subsidence cause flooding in the KMA. The sources of such flooding are high intensity rainfall, storm surges, and cyclonic storms.
* *Developmental factors*: These include unplanned and unregulated urbanization, low capacity drainage and sewer infrastructure that have not kept pace with the growth of the city or demand for services, siltation in available channels, uncontrolled construction in natural drainage areas (marshlands), human-induced subsidence of the area, etc.
* *Climate change aspects*: Changes such as increased intensity of rainfall, sea level rise, and increased storm surges may increase the intensity and duration of flooding events.

Urban flooding is the most critical climate-related hazard in Kolkata. It is a recurring phenomenon the city faces every year during the monsoon period. High intensity rainfall synchronized with high tide in the Hooghly River has almost always resulted in waterlogging in Kolkata. Climate change is likely to intensify this problem through a combination of more intense local precipitation, riverine flooding in the Hooghly, and coastal storm surges. In this paper, the hydrological and hydraulic impacts resulting from increased precipitation in a changing climate by 2050 were studied for Kolkata for two emission scenarios: A1FI and B1 for intense precipitation events.

A major cause of periodic flooding in Kolkata during the rainy season is the deficit in sewer networks and drainage infrastructure. In many places in the older KMC, the hydraulic capacity of the silted main sewer systems is inadequate for drainage during the rainy season. De-siltation of the main sewer, both in the town and suburban systems, is critical to increase the hydraulic capacity and minimize flooding in the core area of the KMC. The results from the SWMM presented in this paper show that the changes in inundation under various flood scenarios between current conditions (30 % silting) and an Adaptation Scenario (0 % silting) could reduce the area affected by flooding by 4 % and the population affected by flooding by at least 5 %.

The current development plans for Kolkata are only up to 2025 and do not account for the possible long-term effects of climate change or any adaptation that may be needed to cope with the problems arising due to climate change over time. The projects currently being implemented or in the pipeline in the KMC were selected using cost–benefit analysis based on impact estimates from current weather-related data. The impacts from climate change were not included in such analysis. However,the likely increased precipitation intensity and sea level rise because of climate change may worsen drainage in Kolkata, causing expansion of the waterlogged areas and longer duration of annual flooding events. Due to the increased flooding and damage caused by climate change, it is likely that the use of cost–benefit analysis using a net present value approach that takes into account climate change effects will increase the viability of many projects not found viable earlier with only current weather data. Hence, there is a need for making the effects of climate an integral part of all future planning for adaptation in Kolkata.

Excerpts from: Susmita Dasgupta, Asvani K Gosain, Sandhya Rao, Subhendu Roy and Maria Sarraf (2013). "A Megacity in a Changing Climate: The Case of Kolkata", *Climate Change, 116:747-766.*