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Road Traffic Injury in Urban Areas: Understanding the Complex City

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Abstract

Over the past 4 decades considerable efforts have been taken to mitigate the growing burden of road injury. With increasing urbanisation along with global mobility that demands not only safety but equitable, efficient and clean (reduced carbon footprint) transport, the responses to dealing with the burgeoning road traffic injury in low- and middle-income countries has become increasingly complex. In this paper, we apply unique methods to identify important strategies that could be implemented to reduce road traffic injury in the Asia and Pacific region; a region comprising large middle-income countries (China and India) that are currently in the throes of rapid motorization. Using a convolutional neural network approach, we classified cities around the world based on urban characteristics related to private motor vehicles and public transport networks. We then identified 689 cities situated within the Asia-Pacific region and assessed the global burden of disease attributed to road traffic injury for urban design clusters. The modelling identified 9 urban cluster types. The majority (64%) of cities in the Asia-Pacific region fall within Clusters 1 and 2 namely, urban form that is sparse with low capacity road infrastructure and limited public transport. Clusters 1 and 2 comprises cities predominantly from China and South Asia with many low- to middle-income cities that are in the throes of considerable urban development. Urban cluster types with both dense road networks (e.g., Clusters Intense and Cul de sac) and public transport (e.g., Clusters High Transit and Motor City) demonstrated lower rates of DALYs lost per 100,000 population for road traffic injury. This study demonstrates the utility of employing image recognition methods to discover new insights to better understand the complex city and how it relates to road traffic injury.

Keywords: Neural networks, urbanisation, city clusters, road traffic injury

1 INTRODUCTION

The burden of road injury is well documented with global trends highlighting between 1990 and 2013, a 15% decrease in the years of life lost and years lived with a disability due to road traffic injury (1). However, hidden behind the declining global rates of road traffic injury, is the fact that in many low and middle-income countries, the global burden of road injury is increasing. For example, the percent change in the rates of disability adjusted life years between 1990 and 2013 for countries in South Asia (comprising one quarter of the world's population) increased by 6% whilst in South and sub-Saharan Africa, it increased a staggering 35% (1). The increasing rates of road traffic injury in low and middle-income countries is explained, in part, by rapid motorization; a direct consequence of increasing urbanization (2).

Globally, the population is rapidly migrating to towns and cities and this is most pronounced in low and middle-income countries. Countries such as India, China and Nigeria, which account for 37% of the world's population, are expected to observe the greatest urban migration (3). For example, over the 10 years to 2010, 226 million Chinese residents migrated from rural to urban areas (4). Living in urban area offers opportunities that are not available elsewhere including opportunities related to greater access to health systems, employment and recreational facilities. However, increased urbanization also means increased exposure to an array of health risks. The health risks associated with rapid motorization in urban areas alone, accounts for an estimated 1.35 million deaths per year due to road injury (5) and 4.2 million deaths per year due to motor vehicle-related air pollution (6) with particulate pollution ($PM_{2.5}$, PM_{10}) reducing average life expectancy by 1.8 years per person (7).

Much has been done to mitigate the growing burden of road injury with many countries implementing road safety strategies that include detailed road safety action plans that are based on decades of established road safety approaches (8). Despite the comprehensive road safety strategies which have targeted (and continue to target) safer roads, road users, speeds and motor vehicles, road safety in the twenty first century is becoming

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more complex. Global mobility is rapidly changing with growing levels of uncertainty. The recent Global Mobility Report 2017 (9) highlights that in the twenty first century not only is there a need to focus on road safety but at the same time transport needs to be equitable, efficient and importantly, it must deliver a considerably reduced carbon footprint.

To achieve not only reductions in road injury whilst at the same time deliver transport systems that are equitable, efficient and 'climate responsive' (9, p 7) a broader response to mitigating the exponential growth in road injury in low- and middle- income countries is needed. This requires a systems-oriented approach as rapidly motorizing low- and middle-income countries are dynamic sociotechnical systems (10). Recent advances in the availability of geospatial information, remote sensing, artificial intelligence, and complexity science provide a unique opportunity to explore the relationships between sociotechnical systems and road injury (11) and thereby begin to understand the complexity of cities with respect to this important health outcome.

This paper applies a unique combination of approaches to classify cities based on urban characteristics related to private motor vehicles and public transport networks. Global burden of disease data attributed to road traffic injury is then examined to assess the extent to which a city's design affects the nature and extent of road traffic injury. We have chosen to focus on cities in the Asia and Pacific region as this region not only includes high- middle- and low-income countries but importantly, the region comprises the largest middle-income countries (China and India) which are currently in the throes of rapid motorization with China comprising more than one quarter of the global road deaths (12).

2 METHOD

A total of 1,667 cities from across the globe with populations exceeding 300,000 residents was identified from the 2015 United Nations world population prospect (3). A subset of these cities namely 689 cities from the Asia and Pacific region were the specific focus; comprising 40 countries ranging from Mongolia in the North, Pakistan in the West, New Zealand in the South and Fiji in the East. Map images from each city were obtained using a 2-stage approach. Details of the 2-stage approach are described in detail in a recent publication (13).

A convolutional neural network (CNN) modelling approach based on 'Inception V3' architecture (14) was applied to the database comprising the map images for each city. CNN is an image classification approach whereby various observations are detected from the original data with each layer in the CNN approach recognizing increasingly detailed features of the data. The convolutional neural network modelling was capable of identifying whether cities could be correctly classified based on the city design characteristics related to road transport. The following characteristics were obtained from the maps namely each city's road network and public transport networks. Other city design elements were also obtained namely, green and blue space. The model was calibrated using 2 stages that involved a supervised learning procedure (15) namely a 'training' stage whereby the model learned which images were associated with which city, and a second stage which validated the performance of the model. During the validation stage, the model assessed the probability that the validation image comes from the map image of the actual city or from one of the remaining cities in the image dataset. In our earlier paper, the validation stage was found to accurately classify images 86% of the time (13).

A graph-based analysis using the Force Atlas 2 algorithm (16) was applied to the database which comprised 1.667 million map images. A spatially representative network graph was then developed. The graph depicts cities that are grouped together meaning such cities are often confused for one another in the model and therefore they appear closer together in the graph. In contrast, cities that are not alike (based on the transport design features) are represented further apart.

The various city groupings were then assessed and described relative to the transport attributes of interest namely the road and public transport networks. To estimate the comparative risk of road injury posed by the transport network design of individual city types, we estimated the intensity of the road and public transport networks in each city by estimating the proportion of the pixel colour count for the respective urban characteristics for each city image.

Disease burden associated with road transport injury (ICD-10-CM V00-V89) was estimated for each city within the various cluster types using data from the Global Burden of Disease (GBD) study (17). As GBD data is only available at the country level, health burden associated city design types was estimated based on the mean country-level data available for individual cities contained within each cluster type. For comparative purposes, road traffic injury was reported as DALYs (Disability Adjusted Life Years) lost, which is a combination of the sum of the years of potential life lost due to premature mortality (YLLs) and years of productive life lost due to a disability (YLDs) per 100,000 people (18).

3 RESULTS

The findings from the convolutional neural network analysis identified nine global clusters of cities in which 1667 cities with populations greater than 300,000 population were classified. Table 1 describes the 9 urban cluster types and lists the proportion of Asia-Pacific cities that fall within the respective clusters. The majority (64%) of low- and middle-income countries in the Asia-Pacific region fall within Clusters 1 and 2. These Clusters comprise cities predominantly from China and South Asia with many of the cities considered low- to middle-income. In contrast, cities from the high-income countries in the Asia-Pacific region namely, Japan, South Korea, Australia and New Zealand are classified in Cluster 6 – the Motor City and Cluster 8 (Intense city cluster).

Figure 1 categories Asia-Pacific countries based on the proportion of city cluster types within each country based on the results of the convolutional neural network analysis. It is evident from Figure 1 that there is considerable variation in cluster types within some countries and absolutely no variation in other countries. For example, among the countries within the Asia-Pacific region (denoted by an asterisk next to the country) there is considerable variation among cities in Vietnam with 4 city clusters identified and similarly in China. In contrast, cities in Papua New Guinea and Mongolia only fall within one cluster – namely the Informal Cluster. This cluster reflects urban form that is sparse, with a low capacity and informal road infrastructure, little public transport, and little formal green space.

Table 1. Urban design clusters and the Proportion of Asia Pacific Cities in each Cluster

Urban Design Cluster Title	Cluster Description	% of Asia Pacific Cities in Cluster
Cluster 1 - Informal	Sparse, low capacity informal road infrastructure, limited rail transport, low formal green space	30.5% (210 cities)
Cluster 2 – Irregular	High green space, mixed formal and informal infrastructure, few high capacity road networks, limited mass transit	33.5% (231 cities)
Cluster 3 - Large blocks	Medium density, formal low and high capacity road networks, medium railed transport	2.8% (19 cities)
Cluster 4 - Cul de sac	Very high density, low capacity mixed formal and informal road networks, low mass transit.	3.8% (26 cities)
Cluster 5 - High transit	Medium density, high capacity, formal road networks, high public transport	0.7% (5 cities)
Cluster 6 - Motor city	Medium to low density, high capacity, grid-based, road networks, medium railed transport	1.7% (12 cities)
Cluster 7 - Chequerboard	High density, medium capacity mixed formal and informal road networks, medium public transport	4.9% (34 cities)
Cluster 8 – Intense	Very high density, mixed formal high capacity and informal road networks, high public transport	4.1% (28 cities)
Cluster 9 – Sparse	Low capacity, low density formal and informal road networks, low public transport	18.0% (124 cities)

The range between the urban cluster types with respect to the proportion of road networks allocated to city land-use is minimal (6.4% to 12.6%) with the Cluster Type – Intense, having the greatest proportion of road network. The urban cluster - Intense has land-use allocated to road networks that is two times greater than the urban cluster type with the lowest proportion of road networks namely, Large Blocks. Interestingly, two thirds of Asia-Pacific cities fall within the Cluster types Informal and Irregular which have only 6.8% and 6.9%, respectively, of the various cities land-use allocated to road networks; this is similar to the cluster with the lowest proportion of road network (Large Blocks with 6.4%). Public transport networks specifically rail networks, are most prevalent in the High Transit city cluster and the Motor City cluster. Both of these clusters have cities from high-income countries including those from the Asia-Pacific region namely, Australia, New Zealand, South Korea, Japan and Singapore.

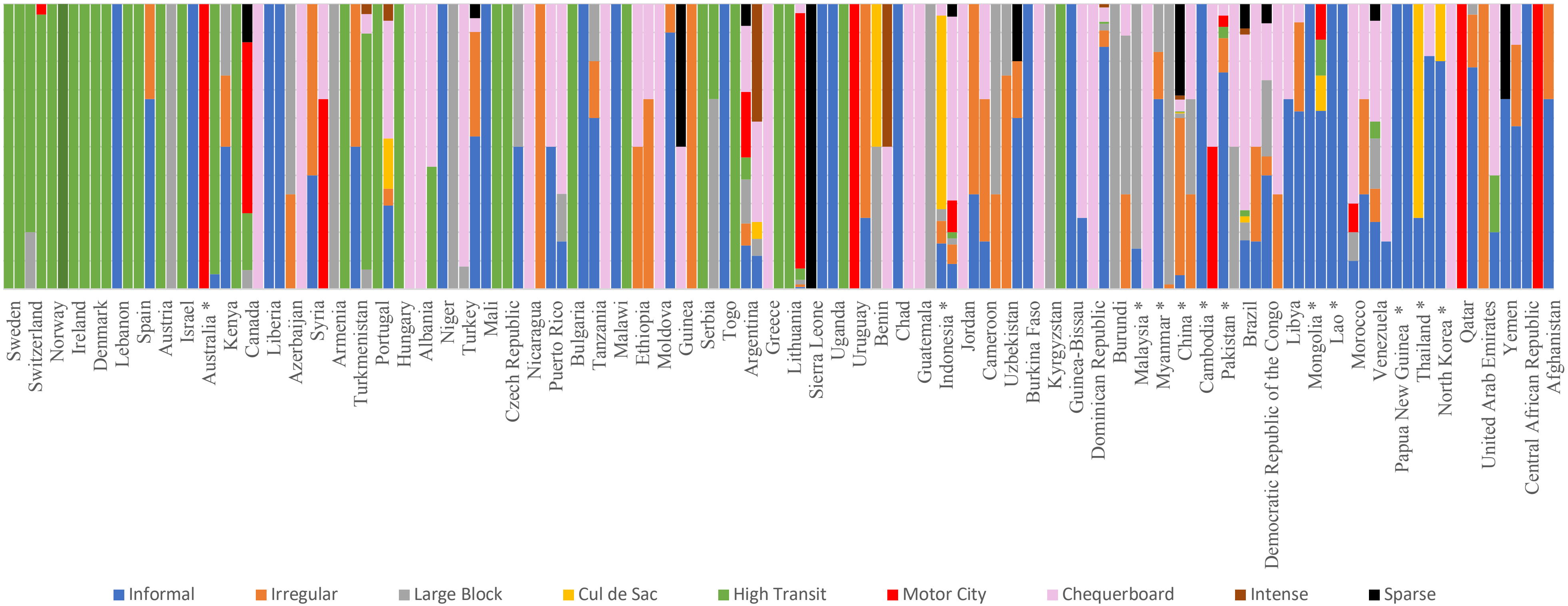

Figure 1. Urban design clusters by country. Asia Pacific Countries denoted by *

A relationship was observed (see Figure 2) between the DALYs attributed to road traffic injury and the proportion of road and public transport networks observed in the respective urban cluster types. Urban cluster types with both dense road networks (e.g., Clusters Intense and Cul de sac) and public transport (e.g., Clusters High Transit and Motor City) demonstrated lower rates of DALYs lost per 100,000 population for road traffic injury. By contrast, urban cluster types that contained sparse road networks (e.g., Clusters Informal and cul de sac) have higher road traffic injury DALYs lost per 100,000 population and this is particularly the case in relation to DALYS lost due to motorcycle related road injury. This relationship was robust with more than 2.5 times difference in DALYS lost to road traffic injury per 100,000 population between the best performing urban cluster types (Clusters 5 and 6, High Transit and Motor City) and the poorest performing urban cluster city types (Clusters 1, 2 and 4 – Informal, Irregular and Cul de Sac).

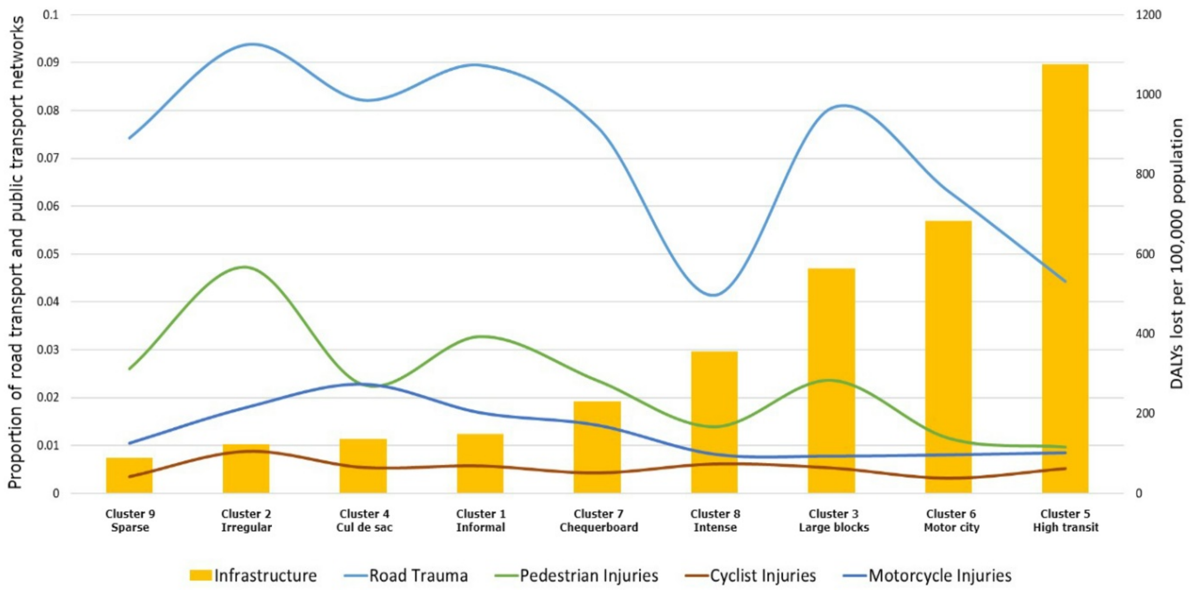

Figure 2. Proportion of road transport and public transport networks by urban cluster type and the estimated DALYS lost per 100,000 population for road traffic injury.

4 DISCUSSION

This study demonstrates the utility of employing image recognition methods to discover new insights related to urban design that are associated with road traffic injury. Furthermore, it focuses on cities in the Asia-Pacific region which is critical given countries in the region account for more than one third of global road deaths (19).

A 2-fold difference in road traffic injury was observed between cities with distinctly different road networks. For example, cities that have invested in public transit have a reduced burden of road traffic injury compared with cities that have limited high capacity road networks, and almost no mass transit systems; the majority of cities in the Asia-Pacific region fall within the latter clusters. Such findings highlight not only that urban form is important in mitigating road traffic injury but also investment in low-risk (relative to private motor vehicle use – including motorcycle use) transport systems is necessary.

This study demonstrates a relationship between land-use associated with road and public transport networks and road traffic injury suggesting that a systems-approach to designing and delivering 21st century cities is of utmost importance to road safety in urban areas. Importantly, such an approach will need to be embraced in the region if global goals such as those established in 2010 by the United Nations General Assembly namely, the Decade of Action for Road Safety which set a target to prevent 5 million road deaths and 50 million serious injuries from road traffic injury by 2020 (20), are to be achieved.

There are a number of limitations in using the image recognition approach to draw causal inferences. These limitations relate specifically to the fact that measures are at an ecologic level and therefore can be influenced by numerous uncontrolled factors including a cities economy and or road safety management practices (21). Nonetheless, the approach highlights the potential utility, at a global level, of such an approach.

The Asia Pacific region is dominated by low- and middle-income countries in which urbanisation and therefore motorization is growing exponentially. The region is currently targeted by Development Banks for infrastructure programs that promote road safety. Despite the focus of the programs on safer speeds, safer people, safer roads and safer vehicles there is limited, if any, focus on reducing motor vehicle use through changes to urban design or land use planning (22). An urgent shift in funding focus is needed in order to mitigate the increasing levels of road traffic injury.

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