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International Journal of Injury Control and Safety Promotion

ISSN: 1745-7300 (Print) 1745-7319 (Online) Journal homepage: https://www.tandfonline.com/loi/nics20

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To cite this article: Mark Stevenson, Jason Thompson, Jasper S. Wijnands, Kerry Nice, Gideon Aschwanden & Haifeng Zhao (2020) Opportunities to reduce road traffic injury: new insights from the study of urban areas, International Journal of Injury Control and Safety Promotion, 27:1, 20-26, DOI: 10.1080/17457300.2019.1704790

To link to this article: https://doi.org/10.1080/17457300.2019.1704790

Published online: 23 Dec 2019.

INTERNATIONAL JOURNAL OF INJURY CONTROL AND SAFETY PROMOTION
2020, VOL. 27, NO. 1, 20–26
https://doi.org/10.1080/17457300.2019.1704790

Opportunities to reduce road traffic injury: new insights from the study of urban areas

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ABSTRACT

Over the past four 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 safe 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-Pacific region; a region comprising large middle-income countries (China and India) that are currently in the throes of rapid motorisation. Using a convolutional neural network approach, we clustered countries containing a total of 1632 cities from around the world into groups based on urban characteristics related to road and public transport infrastructure. We then analysed 20 countries (containing 689 cities) from the Asia-Pacific region and assessed the global burden of disease attributed to road traffic injury and these various urban characteristics. This study demonstrates the utility of employing image recognition methods to discover new insights that afford urban and transport planning opportunities to mitigate road traffic injury at a regional and global scale.

ARTICLE HISTORY
Received 3 August 2019
Revised 17 November 2019
Accepted 11 December 2019

KEYWORDS
Neural networks; urbanisation; city clusters; road traffic injury

Introduction

The burden of road injury is well documented with global trends highlighting, between 1990 and 2013, a 15% decrease in the rates of years of life lost and years lived with a disability due to road traffic injury (Haagsma et al., 2016). 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% (Haagsma et al., 2016). The increasing rates of road traffic injury in low and middle-income countries is explained, in part, by rapid motorisation which is a direct consequence of increasing urbanisation (Pucher, Peng, Mittal, Zhu, & Korattyswaroopam, 2007).

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 (United Nations, Department of Economic & Social Affairs, & Population Division, 2014). For example, over the 10 years to 2010, 226 million Chinese residents migrated from rural to urban areas (Yang et al., 2018). Living in an urban area offers opportunities that are not available elsewhere including opportunities related to greater access to health systems, employment and recreational facilities. However, increased urbanisation also means increased exposure to an array of health risks. The health risks associated with rapid motorisation in urban areas alone, accounts for an estimated 1.35 million deaths per year due to road injury (World Health Organization, 2018a) and 4.2 million deaths per year due to motor vehicle-related air pollution (World Health Organization, 2018b) with particulate pollution (PM2.5, PM10) reducing average life expectancy by 1.8 years per person (Karagulian et al., 2015).

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 (Kahane, 2016). Despite the comprehensive road safety strategies which have targeted (and continue to target) safer roads, safer road users, safer speeds and safer motor vehicles, road safety in the twenty first century is becoming more complex. (Hughes, Newstead, Anund, Shu, & Falkmer, 2015). Global mobility is rapidly changing with growing levels of uncertainty due to new, disruptive technologies. The recent Global Mobility Report 2017 (Sustainable Mobility

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for All, 2017) 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, transport systems must deliver a considerably reduced carbon footprint.

To achieve not only reductions in road traffic injury whilst at the same time deliver transport systems that are equitable, efficient and 'climate responsive' (Sustainable Mobility for All, 2017, 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 motorising low- and middle-income countries are dynamic sociotechnical systems (Dagnachew, 2013). 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 traffic injury (Miller & Tolle, 2016) and thereby begin to provide unique insights which will add to current approaches to mitigating road traffic injury and importantly, begin to deliver more sustainable solutions to safety across the road transport system.

This paper applies a unique combination of approaches to classify countries based on urban (city) 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 urban design characteristics affects the nature and extent of road traffic injury within countries.

Method

A total of 1667 cities from across the globe with populations exceeding 300,000 residents was identified from the 2015 United Nations world population prospect (United Nations et al., 2014). Map images from the identified cities in each country were obtained using a two-stage approach (see Thompson et al., in press for detailed methodology on obtaining the map images). A convolutional neural network (CNN) modelling approach based on the 'Inception V3' architecture (Szegedy, Vanhoucke, Ioffe, Shlens, & Wojna, 2016) was then applied to the database comprising the map images. CNN is an image classification approach whereby each layer in the CNN approach recognizes increasingly abstract features from the original maps. The CNN modelling was designed to identify cities based on 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. The pixel density of the road network and or the public transport network was attained from the maps and used to define the proportions of land-use allocated to these networks. Other city design elements were also obtained namely, green and blue space but were not analysed for this paper. The model was calibrated using two stages that involved a supervised learning procedure (Kohavi & Provost, 1998) namely a training stage whereby the CNN model learned which images were associated with which city, and a second stage then validated the performance of the model. During the validation stage, the model assessed the probability that the validation image came from the map image of the actual city or from one of the remaining cities in the image dataset – either from cities within the same country or another country. This approach in machine learning is referred to as a matching matrix or a confusion matrix as it visually presents whether the system is confusing cities for example. The validation of the model indicated that the CNN model accurately classified city images 86% of the time (see Thompson et al., in press for details on the validation process).

A force-directed graph-based analysis (Fruchterman & Reingold, 1991) was then applied to the confusion matrix of the final CNN classification table. The classification table was reduced in size so that it represented countries containing cities that were regularly confused for one another by the CNN. This produced a spatially representative graph where countries that contained cities often confused for one another in the model (based on the transport design features) appeared closer together and those not alike were represented further apart. A modularity analysis was then applied to the graph to identify *groups or clusters* of countries that were more often confused for one another in the model indicating they contained similar transport-related characteristics (road networks and public transport) in their urban design.

As the CNN model identified unique clusters of countries including cities with corresponding transport-related characteristics, we applied estimates of the mean disease burden associated with road transport injury (ICD-10-CM V00-V89) for each country type within the various identified cluster types using data from the Global Burden of Disease (GBD) study (GBD DALYs & Collaborators, 2017). For comparative purposes, road traffic injury was reported as DALYs (Disability Adjusted Life Years) lost per 100,000 population per annum, 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 population (Murray et al., 2012).

A subset of countries from the Asia-Pacific region (comprising 689 cities) were the focus of this paper. The Asia-Pacific region comprises 40 countries ranging from Mongolia in the North, Pakistan in the West, to New Zealand in the South (see Figure 1 for the geographical distribution of the countries in the Asia and Pacific region). We have chosen to focus on countries (and associated cities) in this region as the 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 motorisation with China comprising more than one quarter of the global road deaths (Haagsma et al., 2016).

Results

The CNN modelling identified 11 global clusters of countries, based on the urban characteristics of interest namely, road and public transport networks. Figure 2 highlights the confusion matrix derived from the CNN modelling.

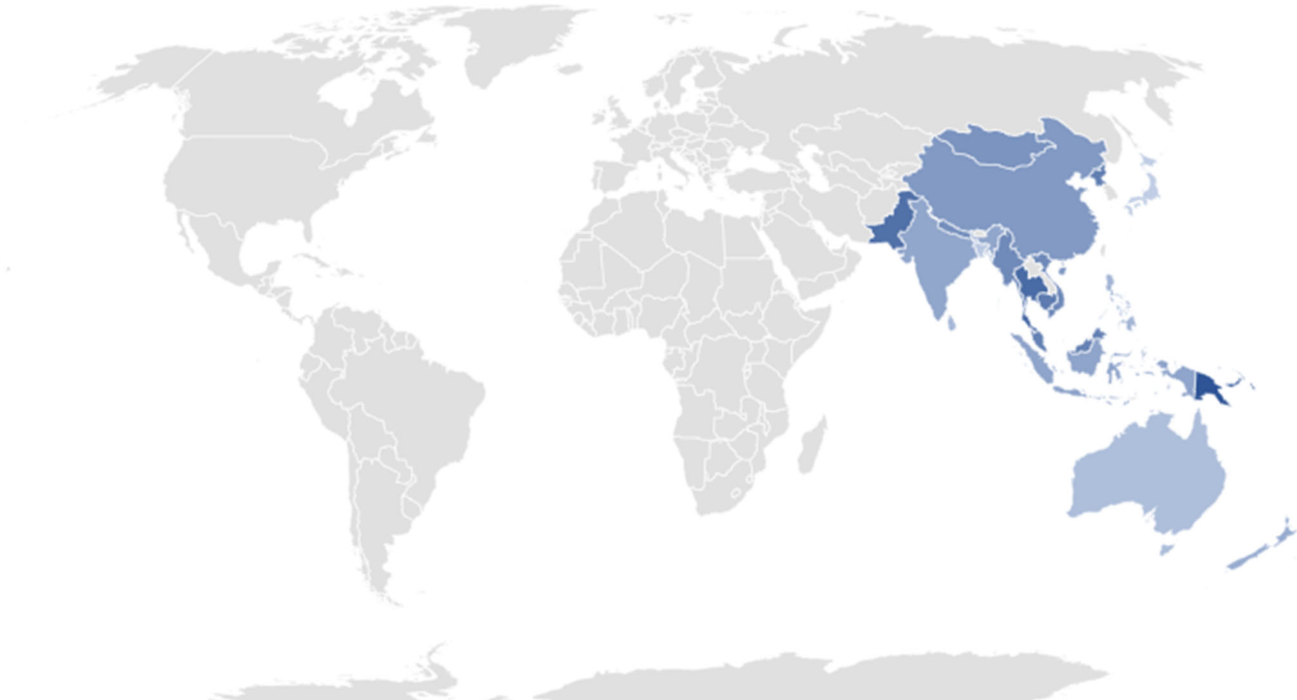

Figure 1. Geographical distribution of the Asia-Pacific countries.

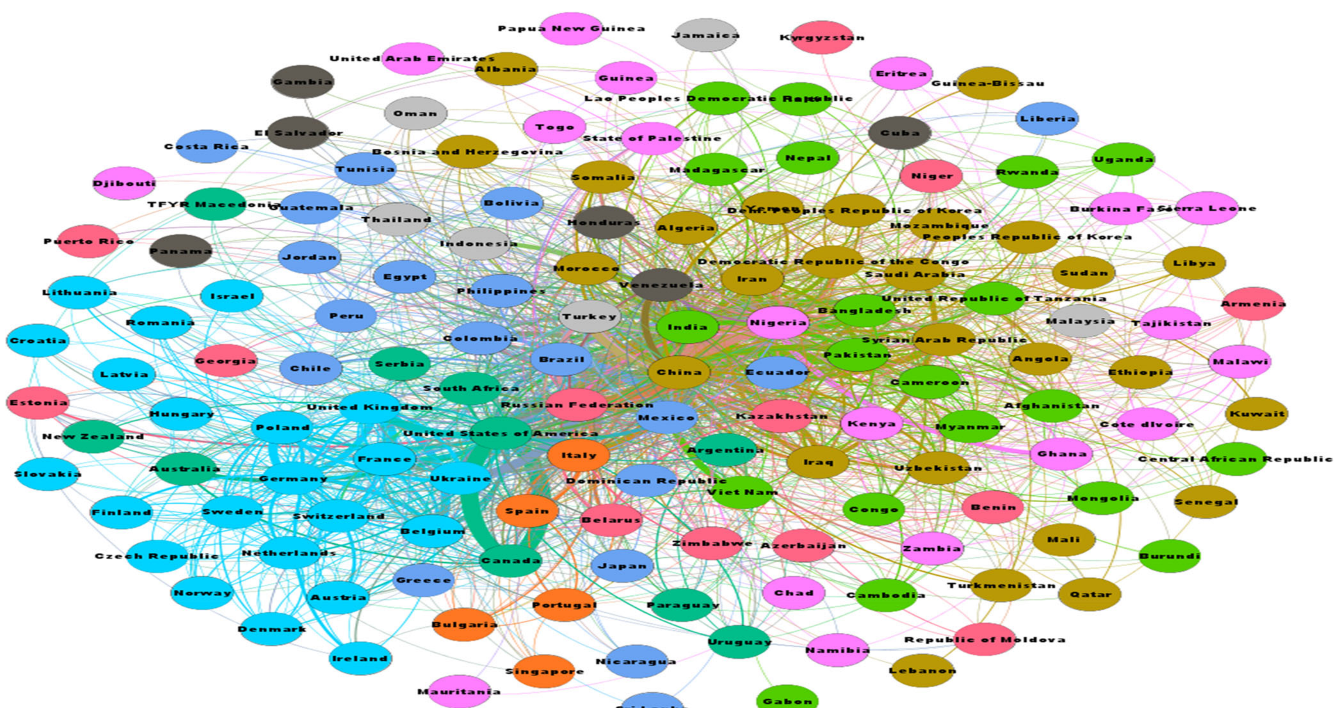

Figure 2. Network graph depicting the confusion-matrix produced by the CNN.

Countries across the globe are represented as coloured nodes (11 colours to represent each of the clusters) and the vertices represent the extent to which cities from within countries were confused for one another by the CNN, indicating similarities in road and public transport networks within countries. Figure 3 illustrates the geographical distribution of the eleven clusters, globally.

The majority of countries (85%, n = 34) from the Asia-Pacific region fall within 5 of the cluster groups with most Asia-Pacific countries in Cluster/Group 2 (see Table 1). As evident in Table 1, the least public transport densities are observed in cities from countries in Cluster/Group 2; this cluster or group of countries comprise 40% of Asia-Pacific countries. These countries have minimal investment in public transport and have the greatest burden of DALYS lost to road trauma (along with countries in Cluster or Group 9) in the region. This highlights an important finding arising from this research namely, that countries that have limited

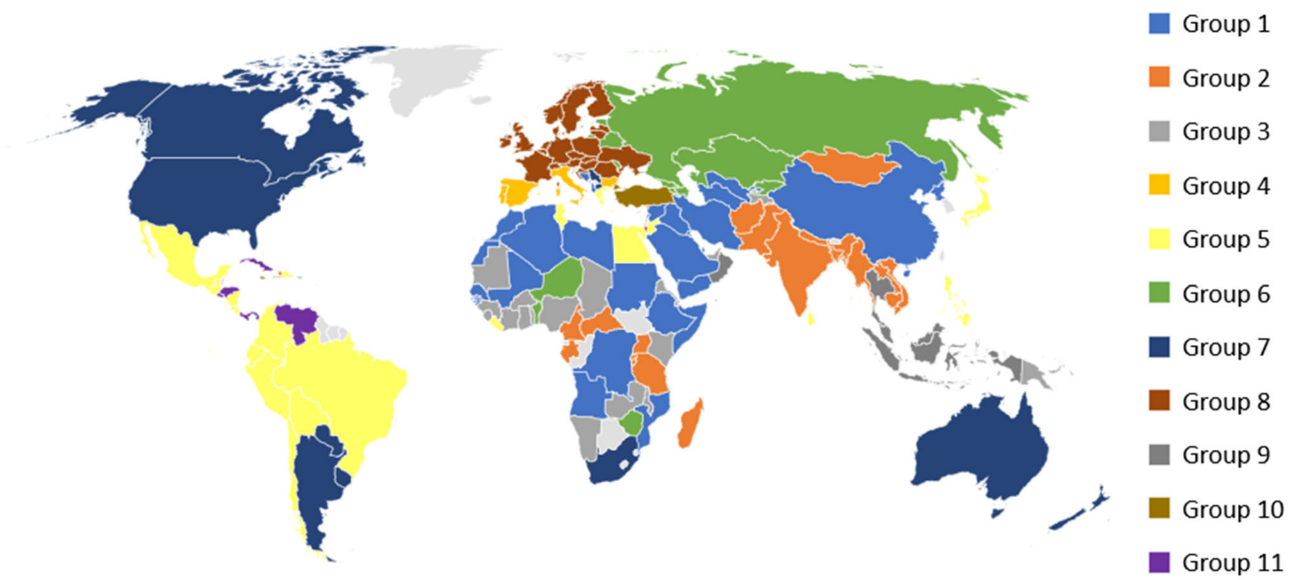

Figure 3. Geographic distribution of the 11 country-level clusters.

Table 1. Proportion of public and road transport densities per country cluster/group and mean DALYs lost to road trauma.

Country Group	Public Transport Density*	Road Network Density*	Proportion of Asia-Pacific Countries in Group	Mean (sd) DALYs lost to road trauma per 100,000 population per annum
Group 1	0.06%	7.5%	10%	1067 (462)
Group 2	0.04%	5.5%	40%	1324 (875)
Group 3	0.07%	5.8%	5%	938 (379)
Group 4	0.56%	9.8%	5%	422 (214)
Group 5	0.18%	9.5%	15%	844 (385)
Group 6	1.37%	5.3%	0%	795 (301)
Group 7	0.39%	7.7%	10%	714 (324)
Group 8	0.95%	7.2%	0%	487 (201)
Group 9	0.09%	8.2%	15%	1481 (667)
Group 10	0.10%	8.6%	0%	542 (62)
Group 11	0.05%	8.7%	0%	576 (293)

*Proportion of Land-use allocated to public transport or road networks

public transport have the highest burden of road injury in the region.

Table 1 also highlights that Cluster 4 (Group 4 - Singapore) has the lowest DALYs lost per 100,000 population per annum followed by Cluster 7 comprising Australia and New Zealand. The burden of injury lost to road trauma in Singapore (422 per 100,000 population per annum) is 60% lower than Cluster 7 (714 per 100,000 population per annum). In contrast, countries that fall in Cluster 2 (see Table 2) have three times the burden of road trauma compared to Singapore. The burden of road trauma grouped by cluster type (see Figure 4) highlights that the countries falling in Clusters 1,2,5, and 9 account for 80% of the Asia-Pacific countries and more than 50% of the overall global burden of road injury.

The densities of public transport and road networks provide a unique insight with respect to urban designs of cities across countries. Table 1 highlights that the density of land-use dedicated to public transport is greatest in Cluster 6; Russia and Eastern European countries followed by Cluster 8 - countries in Western Europe. Singapore, in Cluster 4 (Group 4) has the highest proportion of any country in the Asia-Pacific region in relation to the density of land-use dedicated to public transport. In relation to the density of land-use allocated to roads, Singapore, as an Asia-Pacific coutnry has the highest proportion of land-use allocated to roads. The other countries in the Asia-Pacific region with medium density road networks are Japan, the Philippines and Sri Lanka (Cluster 5) along with Indonesia, Malaysia and Thailand (Cluster 9). Despite Singapore having the largest density of road networks in the Asia-Pacific region (approximately 10% of land-use provision is for roads) it delivers a low-risk environment in relation to road traffic injury. In contrast, Indonesia, Malaysia and Thailand have slightly reduced land-use provision for roads (∼8%) however, the burden of road injury is 3.5 times that of Singapore.

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 countries in the Asia-Pacific region which is critical given the Asia-Pacific region accounts for more than one third of the global road deaths (Institute for Health Metrics & Evaluation, 2015) and where road deaths are increasing exponentially (Haagsma et al., 2016).

A three-fold difference in the burden of road traffic injury was observed between countries with distinctly different land transport networks. For example, countries (and their respective cities) that have invested in public transport have a reduced burden of road traffic injury compared with cities that have limited high-capacity road networks, and almost no public transport systems; the majority of cities in countries in the Asia-Pacific region fall within the latter clusters.

The findings highlight a relationship between land-use associated with road and public transport networks and the burden of road traffic injury suggesting that land-use decisions and the type of land transport systems delivered across countries are important elements to delivering road safety in urban areas. Considerable safety benefits could be achieved by integrating road safety within the entire transport system and transport policies that embrace new urban mobility namely policies that incentivise walking, cycling (on infrastructure separated from motorized vehicles) and public transport. Such an approach leads to the support for a compact city approach to urban and transport planning namely, a city of short distances in which there are higher residential and population densities, greater mixed land-use and urban design amenable to walking and cycling (Gordon & Richardson, 1997).

To benefit from a compact-city approach, cities will need to move away from subsidising private motor vehicle use (European Commission, 2011) and move towards policies that support both safe and sustainable transport. To achieve road safety targets as proposed in the UN Decade for Road Safety 2011–2020 and to achieve the expectations of the UN Sustainable Development Goals (United Nations, 2018), it will be necessary to understand the role of urban and transport planning in contributing to a reduction in road deaths and serious injury. This does not solely imply studying master urban plans implemented across established high-income countries but to also observe 'natural' case studies from low and middle-income countries bereft of urban and transport planning approaches. For example, in Delhi, India, urban and transport plans were never implemented or if implemented, never in their entirety, resulting in a polycentric city that has organically evolved (Mohan, Tiwari, & Mukherjee, 2016). Delhi is a city with significant levels of active and public transport use (Stevenson et al., 2016), and a city of short distances (minimal vehicle kilometres travelled) in part, because low-income residents are residing in informal settlements close to their place of work. Cities such as Delhi that continues to invest in 'cleaner' public transport, comprises a city of shorter commuter distances (albeit due to unplanned circumstances) and continues to operate a multi-modal transport system that is well placed to transition to safe and more sustainable transport solutions.

The findings from this study highlight not only that urban and transport planning are important in mitigating road traffic injury but also investment in low-risk (relative to private motor vehicle use) transport systems are necessary. The current Safe System approach to road safety (The UN Road Safety Collaboration, 2010), which is a strategy endorsed across many high-income highly motorised countries and, increasingly, advocated in low- and middle-income countries,

Table 2. Countries from the Asia-Pacific region with estimated DALYs lost per 100,000 population by Asia-Pacific country and cluster/group.

Country	DALYs lost to road trauma per 100,000 population	Country group
China	953	1
North Korea	1254	1
Bangladesh	408	2
Cambodia	1301	2
India	801	2
Mongolia	1025	2
Myanmar	1133	2
Nepal	1072	2
Pakistan	1429	2
Viet Nam	1133	2
Papua New Guinea	1756	3
Singapore	106	4
Japan	350	5
Philippines	622	5
Sri Lanka	591	5
Australia	530	7
New Zealand	722	7
Indonesia	822	9
Malaysia	1217	9
Thailand	1491	9

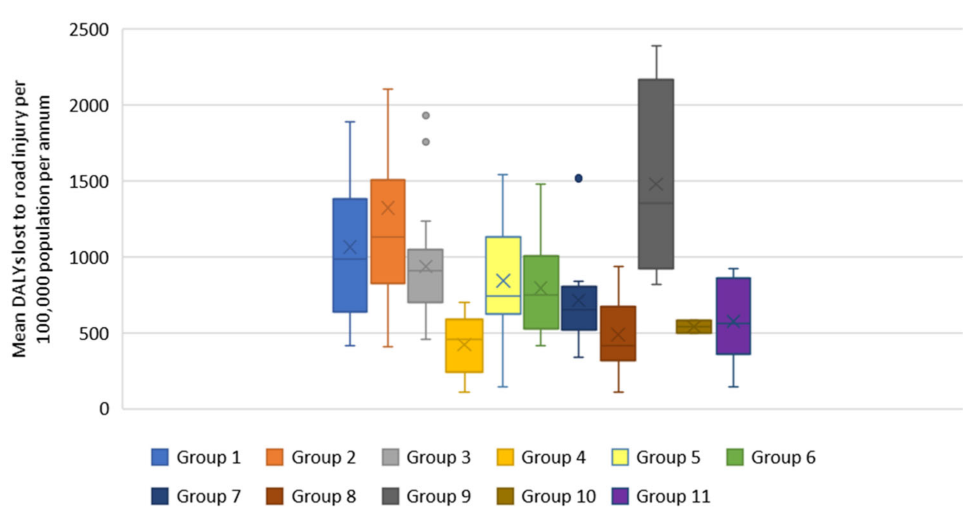

Figure 4. Mean DALYs lost to road trauma per 100,000 population per annum for country cluster/group.

places minimal emphasis on urban planning and the integration of multiple transport modes across the transport system (particularly the integration of public transport). Further, many country/city-specific strategies continue to focus attention on tangible short- to mid-term safety targets which tend to silo the safety response to one government portfolio, thereby reducing the likelihood of a comprehensive systems-focused approach to delivering safe and sustainable transport. If jurisdictions continue to place considerable focus on delivering measurable short-term outputs that focus on placing the private motor vehicle as the key transport system, there will be limited resources directed towards important transport planning solutions at a time when the digital revolution provides new opportunities to deliver a safe and sustainable road transport system.

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 city or coutnries economy and or road safety management practices (World Health Organization, 2018a). 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 motorisation 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 land use or transport planning (Davies & Roberts, 2014). An urgent shift in funding focus is needed in order to mitigate the increasing levels of road traffic injury.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

Dagnachew, A. G. (2013). *Leapfrogging towards sustainable mobility: Enablers of sociotechnical transition towards a sustainable urban mobility system in developing country cities. The case of Bangalore and Jakarta* (Masters thesis). Utrecht University, Utrecht, The Netherlands.

Davies, G. R., & Roberts, I. (2014). Is road safety being driven in the wrong direction? *International Journal of Epidemiology*, *43*(5), 1615–1623. doi:10.1093/ije/dyu103

European Commission. (2011). *WHITE PAPER - Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system*. Luxembourg, Europe: European Union.

Fruchterman, T. M., & Reingold, E. M. (1991). Graph drawing by force-directed placement. *Software: Practice and Experience*, *21*(11), 1129–1164. doi:10.1002/spe.4380211102

GBD DALYs, & Collaborators, H. (2017). Global, regional, and national disability-adjusted life-years (DALYs) for 333 diseases and injuries and healthy life expectancy (HALE) for 195 countries and territories, 1990-2016: A systematic analysis for the Global Burden of Disease Study 2016. The Lancet, *390*(10100), 1260–1344. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/28919118 doi:10.1016/S0140-6736(17)32130-X

Gordon, P., & Richardson, H. W. (1997). Are compact cities a desirable planning goal? *Journal of the American Planning Association*, *63*(1), 95–106. doi:10.1080/01944369708975727

Haagsma, J. A., Graetz, N., Bolliger, I., Naghavi, M., Higashi, H., Mullany, E. C., … Phillips, M. R. (2016). The global burden of injury: Incidence, mortality, disability-adjusted life years and time trends from the Global Burden of Disease study 2013. Injury Prevention, *22*(1), 3–18. Retrieved from https://injuryprevention.bmj.com/content/injuryprev/22/1/3.full.pdf doi:10.1136/injuryprev-2015-041616

Hughes, B. P., Newstead, S., Anund, A., Shu, C. C., & Falkmer, T. (2015). A review of models relevant to road safety. *Accident Analysis & Prevention*, *74*, 250–270. doi:10.1016/j.aap.2014.06.003

Institute for Health Metrics and Evaluation. (2015). Global burden of disease study. Seattle, WA: Institute for Health Metrics and Evaluation.

Kahane, C. J. (2016). *Comparison of 2013 VMT fatality rates in U.S. States and in high income countries* (Report No. DOT HS 812 340). Washington, DC: National Highway Traffic Safety Administration.

Karagulian, F., Belis, C. A., Dora, C. F. C., Prüss-Ustün, A. M., Bonjour, S., Adair-Rohani, H., & Amann, M. (2015). Contributions to cities' ambient particulate matter (PM): A systematic review of local source contributions at global level. *Atmospheric Environment*, *120*, 475–483. Retrieved from http://www.sciencedirect.com/science/article/pii/S1352231015303320. doi:10.1016/j.atmosenv.2015.08.087

Kohavi, R., & Provost, F. (1998). Confusion matrix. *Machine Learning*, *30*(2-3), 271–274. doi:10.1023/A:1007442505281

Miller, H., & Tolle, K. (2016). Big data for healthy cities: Using location-aware technologies, open data and 3D urban models to design healthier built environments. *Built Environment*, *42*(3), 441–456. doi:10.2148/benv.42.3.441

Mohan, D., Tiwari, G., & Mukherjee, S. (2016). Urban traffic safety assessment: A case study of six Indian cities. *IATSS Research*, *39*(2), 95–101. Retrieved from http://www.sciencedirect.com/science/article/pii/S0386111216000054. doi:10.1016/j.iatssr.2016.02.001

Murray, C. J. L., Vos, T., Lozano, R., Naghavi, M., Flaxman, A. D., Michaud, C., … Lopez, A. D. (2012). Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990–2010: A systematic analysis for the Global Burden of Disease Study 2010. *The Lancet*, *380*(9859), 2197–2223. doi:10.1016/S0140-6736(12)61689-4

Pucher, J., Peng, Z. r., Mittal, N., Zhu, Y., & Korattyswaroopam, N. (2007). Urban transport trends and policies in China and India: Impacts of rapid economic growth. *Transport Reviews*, *27*(4), 379–410. doi:10.1080/01441640601089988

Stevenson, M., Thompson, J., de Sá, T. H., Ewing, R., Mohan, D., McClure, R., … Woodcock, J. (2016). Land use, transport, and population health: Estimating the health benefits of compact cities. *The Lancet*, *388*(10062), 2925–2935. doi:10.1016/S0140-6736(16)30067-8

Sustainable Mobility for All. (2017). *Global mobility report 2017: Tracking sector performance*. Washington, DC: License: Creative Commons Attribution CC BY 3.0.

Szegedy, C., Vanhoucke, V., Ioffe, S., Shlens, J., & Wojna, Z. (2016). Rethinking the inception architecture for computer vision. *Proceedings of the IEEE conference on computer vision and pattern recognition*. Las Vegas, NV.

The UN Road Safety Collaboration. (2010). *Global plan for the decade of action for road safety 2011–2020*. Geneva, Switzerland: World Health Organization.

Thompson, J., Stevenson, M., Wijnands, J. S., Nice, K., Aschwanden, G., Silver, J., … Morrison, C. N. (in press). Injured by design: A global perspective on urban design and road transport injury. *The Lancet*. Retrieved from https://ssrn.com/abstract=3307635

United Nations. (2018). *The sustainable development goals report 2018*. New York, NY: United Nations.

United Nations, Department of Economic and Social Affairs, Population Division. (2014). *World urbanization prospects: The 2014 revision, highlights (ST/ESA/SER.A/352)*. New York, NY: United Nations.

World Health Organization. (2018a). *Global status report on road safety 2018*. Geneva, Switzerland: World Health Organization.

World Health Organization. (2018b). *WHO air pollution*. Geneva, Switzerland: World Health Organization.

Yang, J., Siri, J. G., Remais, J. V., Cheng, Q., Zhang, H., Chan, K. K. Y., … Gong, P. (2018). The Tsinghua & Lancet Commission on Healthy Cities in China: Unlocking the power of cities for a healthy China. *The Lancet*, *391*(10135), 2140–2184. doi:10.1016/S0140-6736(18)30486-0