

A REVIEW ON PRIORITIZING PHYSICAL SAFETY AND COMFORT IN URBAN SUSTAINABILITY ASSESSMENT TOOLS TO EFFECTIVELY CONTROL ACCIDENTS IN STREETS OF COLOMBO

KUMARAGURUPARAN, A.^{1*}, WIJESUNDARA, K.W.J.P.² & WEERASINGHE, U.G.D.³

^{1,2,3}Department of Architecture, University of Moratuwa, Sri Lanka

¹ahranya@gmail.com, ²jwijesundara@uom.lk, ³gamiweer@uom.lk

Abstract: The concept of sustainability has evolved since its initial definition by the Brundtland commission in 1987, and become comprehensive over time with inclusion of well-defined social, environmental and economic aspects. In order to understand the progress of sustainability, and facilitate decision making, various sustainability assessment tools were established. Today it has become necessary to include safety and comfort as criteria of such sustainability assessment tools, considering the high number of accidents and crimes taking place in urban contexts despite all the legal reforms made through several years to control user mis-behaviours. A high number of road accidents are recorded in Colombo as per the report issued by the Sri Lanka Department of Census and Statistics. This is primarily due to lack of obligation to enforce physical safety and comfort aspects. Establishing physically safe and comfort streets could contribute to prevent as well as reduce accidents by spontaneously directing users in the right way. Therefore, considering sustainability principles, and sustainability rating, being a well-established universal quality assessment, it is important to incorporate physical safety and comfort as a criteria of sustainability rating of urban streets. The review is done by initially defining sustainability through literature review, identifying the research gap on physical safety and comfort using VOSviewer software, and assessing the significance of safety and comfort in assessing urban streets using available online data. It is identified that physical safety and comfort is not included in most of the sustainability assessment tools. It is suggested that inclusion of these criterion could contribute in effectively reducing the street accidents. Summary of this review could contribute in further research based on sustainability tool criteria assessments.

Keywords: *Sustainability; physical safety; physical comfort; street accidents; Colombo.*

1. Introduction

Physical safety and comfort of a space is considered as the physical ease and protection sensed by the user, when components of design that ensure the safety and comfort are established suitable to location, with ergonomic standards (Ahmed-Kristensen, and Stavrakos, , 2012). Quality and adequacy of physical elements are significant components that determine the effective usage of streets (Khder et al., 2016). Appropriately combining such components with suitable design layout directs people to spontaneously abide to the regulations and thereby ensure safety and comfort. Therefore emphasising the implementation of physical safety and comfort aspects could be an efficient method of controlling street traffic accidents as suggested in the United Nations Global Status Report (WHO, 2018), in addition to all other traditional methods such as managing traffic flow, and legal reforms, that have been proven ineffective through sustaining high rates of accidents recorded by Sri Lanka Department of Census and Statistics (2019). Though it is ideal to incorporate these guidelines with street design regulations, the pragmatic approach would be to include them as elements of 'sustainability', which is currently a well-recognised quality assessment criteria, and universally trending design 'status'.

The economic, environmental, and social aspects were considered the 'three pillars' of sustainable development concept and later in 1995, political-institutional was added as a fourth dimension (Burford et al., 2013). None of those 'pillars' emphasise the implementation of physical safety and comfort aspects in street or any public realm, other than urban renewal concepts that focus on improving physical conditions of buildings as stated by Yıldız et al. 2020). It is observed that the definition of sustainability had evolved over time with inclusion of diverse fields of development. However, neither the latest definitions by the United Nations nor their development goals specify the

*Corresponding author: Tel: +94 774974647 Email Address: ahranya@gmail.com
FARU Journal: Volume 09 Issue 1 DOI: <http://doi.org/10.4038/faruj.v9i1.114>

requisite of physical safety and comfort. Further, the code on physical comfort proposed by the National Institute of Building Sciences (2018) of the United States of America [USA], is limited to elements of buildings to ensure human comfort. Global street design guide by Global Design Cities Initiative (2016), that addresses physical safety and comfort is a reference document for street design and therefore is not necessarily adhered to. There is no well-defined universal code of practice or regulation that ensures physical safety and comfort at public realm, especially at streets where human are more vulnerable to unforeseen mishaps such as accidents.

Streets are essential public element that provide a network of access to other urban spaces (Michaela and Prescott, 2015). Streets that take up a great percentage of urban space fails to provide safety and comfort to users (National Association of City Transportation Officials [NACTO], 2017). As per the Sri Lanka Department of Census and Statistics (2019), a higher number of road accidents are recorded in Colombo than any other parts of the country. In the year of 2019 the number of road accidents reported to police in the country is 30,433; in Colombo it is 3326 which is 10.92% of total accidents in the country, and persons killed in Colombo due to road accidents is 2829 (Sri Lanka Department of Census and Statistics, 2019). The global sustainable goal is to halve this number of deaths by 2020 (World Health Organisation, 2017). From 2013 to 2019, the number of accidents are reported to have been reduced by 19.66 %, and yet the number of persons killed due to road accidents had increased from 2013 to 2018 by 25.05% and again from 2018 to 2019 reduced by only 9.91% (Figure 5) (Department of Census and Statistics, 2018). Therefore, in overall, from 2013 to 2019 the number of accidents has reduced only by 48%, while number of deaths has increased by 19% (Department of Census and Statistics, 2018). Therefore it could be stated that Sri Lanka had failed to achieve the global sustainable goal. No comprehensive research has been conducted to identify the major cause for high rates of such accidents. However, the above statistics proves the periodic reformation of traffic laws and planning as ineffective methods to control the traffic mishaps.

The United Nations Global Status Report (WHO, 2018) depicts the universality of the problem. Road traffic crashes are globally identified as the ninth top cause for death at all ages (WHO, 2017). The World Health Organisation Facts Sheet on Road Traffic Injuries (2020) states that globally approximately 1.35 million people die, and about 20-50 million people get injured annually due to road traffic crashes, and more than 50% of them are vulnerable users such as pedestrian, cyclists and motorcyclists. The severity of road crashes leads to social as well as economic problems. It costs around 1-3% of the National Gross Product of any country (WHO, 2017). The report suggests a safe road that accommodates human error, though the main causes of accidents are: over speeding, driving under psychoactive substance, ignorance of wearing helmets and seat belts, etc. (WHO, 2020). The roads should be designed in such a way to spontaneously make the users adopt to the road safety aspects (WHO, 2017). Including such design guides ensuring physical safety and comfort as criteria of sustainability assessment is vital in promoting a safe and comfort street design.

Sustainability assessment is conducted using different assessment tools as they contribute to effectively incorporate sustainability (National Research Council, 2011). Sustainability assessment tools are analytical techniques that provide data to assist decision making (Gasparatos et al., 2009). Thus, the research aim is to identify the significance of physical safety and comfort as a criteria of sustainability assessment tools in evaluating urban public realm, to reduce the rate of road accidents.

2. Methodology

The severity of road accidents is identified from global as well as Sri Lankan reports and statistics. The literature review is carried out to: summarise the globally accepted definitions of sustainability, and identify the significance and inclusion of the physical safety and comfort aspects in sustainability assessment tools regarding designing urban streets and thereby reducing street accidents. Identifying knowledge gap in research is done based on bibliometric analysis of SCOPUS database using VOSviewer software. Bibliometric analysis contributes to trace the intellectual structure of the field of study, allowing for a well-structured literature review (Bigliardi and Filippelli, 2022). Elsevier's abstract and citation database SCOPUS is selected as it includes a large number of international peer reviewed research articles of high impact factor from all disciplines (Díaz-López, et al., 2019). Science mapping software VOSviewer is used to efficiently carryout the analysis based on relevant keywords with graphical interpretations. . Journals selected for analysis are limited to publications in English, extracted from the SCOPUS research journal database. Journals that discuss sustainable development based upon physical safety and comfort are obtained through application of Boolean expression: '(("physical safety" OR "physical comfort") AND sustainability)' in order to choose the most relevant articles to the research topic. Accordingly 16 journals are summarised within the period of 10 years, from 2010 to 2020. Significance of physical safety and comfort of streets in reducing accidents, and it's requisite in the sustainability assessment tools are analysed with case study of Colombo, and supportive literature source. City of Colombo is chosen for analysis as it is the urban area that records highest number of road accidents in Sri Lanka as per Department of Census and Statistics, (2018). The report of 2018 is considered for

analysis as the transport pattern has been deviated and traffic has reduced from the norm due to COVID-19 and consecutive crisis.

3. Scope and limitations

Literature review on sustainability concept and sustainability assessment tools are limited to sources available online. Knowledge gap identification is limited to SCOPUS database as it is the only accessible licensed research citation database with a vast collection of highly standardised research articles supported by the VOSviewer software. The assessment of state of road accidents is limited to United Nations global report and Sri Lanka police records published by the Sri Lanka Department of Census and Statistics instead of onsite data collection, due to the existing COVID-19 travel restrictions and safety precautions.

4. Literature Analysis

Analysis through VOSviewer software depicts (Figure 1) negligence of overall physical safety and comfort in considering a sustainable development in the public realm. It could also be observed that only most recent research topics are more relevant towards urban sustainability, and analyses the rating tools, yet do not specify or discuss physical safety and comfort of public realm (Figure 1). This analysis proves that physical comfort is widely assessed based on the thermal and environmental factors depicted through keywords such as: ‘thermal comfort’, ‘climatic adoption’, ‘green building’, ‘air flow’, ‘climatology’, etc. rather than on ergonomics or anthropometrics. Research articles on sustaining communities and other social aspects have been discussed as a major component of sustainable urban design, and a knowledge gap exists regarding the inclusion of physical safety and comfort.

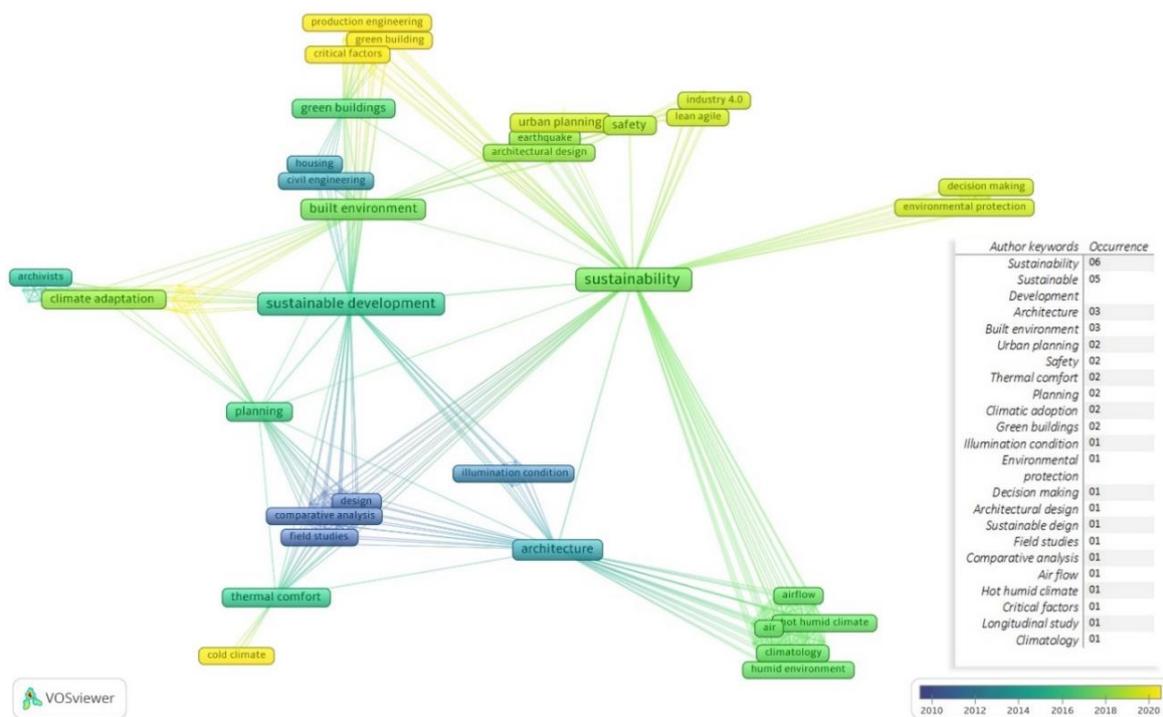


Figure 1, Network visualisation of author keywords of all research articles in the SCOPUS (VOSviewer, 2021)

Figure 02 depicts the keywords that are more relevant to physical safety and comfort, which have been conducted only at recent period, however do not address the basic ergonomic or anthropometric criteria. Most research on sustainability in urban development focus on the USA, China, Turkey, Italy, The United Kingdom, Bangladesh, Australia etc. and not on contexts similar to Sri Lanka.

It is vital that research on significance of physical safety and comfort and inclusion of this element in assessing the sustainability of public realm to reduce street accidents be carried out on the Sri Lankan context where traffic fatality number still remains high as per the Department of Census and Statistics (2019). This knowledge gap is confirmed through VOSviewer software bibliometric analysis on keywords (figures 1, and 2).

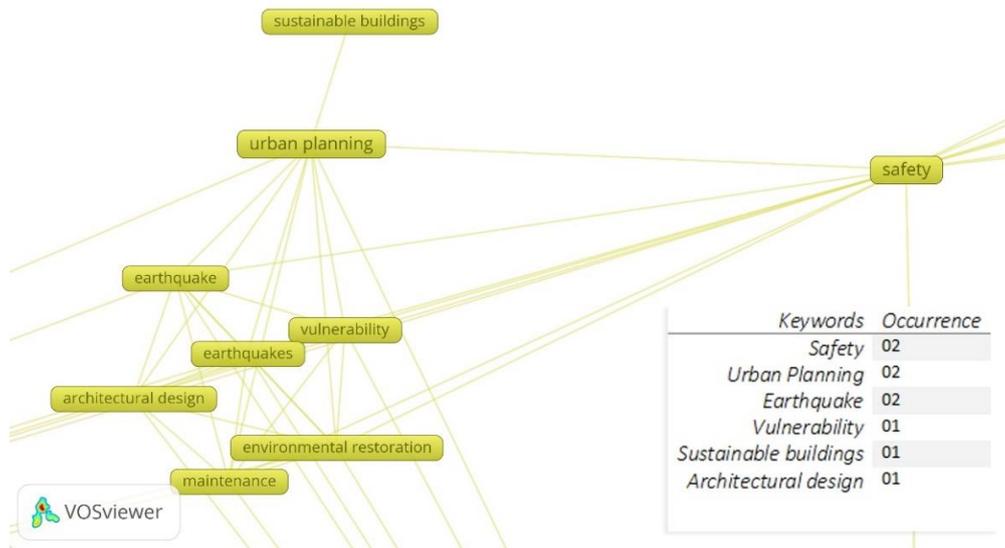


Figure2, Most relevant keywords to physical comfort and safety of all research articles in the SCOPUS (VOSviewer, 2021)

5. Significance of physical safety and comfort in reducing street accidents

Streets which are the major connectors of places, occupy a greater percentage of urban space and yet fail to ensure user safety and comfort (National Association of City Transportation Officials [NACTO], 2017). Urbanisation and urban population are frequently increasing (The World Bank, 2020b), and simultaneously the road accident death rates are also increasing (WHO, 2018). Sri Lanka records the worst road accident fatalities amidst the South Asian region (WHO, 2018), while the vehicle ownership also rapidly increases (The World Bank, 2020a). The main causes for road accidents in Sri Lanka as identified by Perera, Clifford (2016) and The World Bank (2020a) are: negligence of users, increased vehicular numbers while the road expansions are insufficient and poorly connected, inefficient legal system, and poor public transport system. Through years the legal system has been reformed to ensure safety (The World Bank, 2020a) and yet the number of fatalities are continuously rising (Department of Census and Statistics, 2019). However, the legal reforms focus on charging the users for misbehaviour and re-arranging the traffic flow, but not on improving the physical street structure to prevent accidents. Therefore, as stated by the WHO (2018), regardless of the cause, it is important to design streets complying with standards to ensure physical safety and comfort of users to spontaneously direct the users in the right path, and to incorporate protective elements such as buffers. Despite the causes, it is the physical collisions that result in injuries and deaths (Harper, 1953), therefore roads should be designed appropriately to prevent physical collisions.

Elevating road safety in the streets of Colombo is vital to augment the well-being of people as well as the national economy (The World Bank, 2020). The Sri Lankan authorities responsible for management of road safety are ineffective due to the lack of power, resources, and tools, and it is necessary to establish a tool to assess, implement and maintain road safety to ensure physical safety and comfort, which is the prime solution to the research problem (The World Bank, 2020). Therefore, as discussed, sustainability tools are the globally accepted and well established models, through which implementation of physical safety and comfort could be ensured.

6. Significance of physical safety and comfort within the international concept of sustainability

Providing elements such as shading devices through walkways, which ensure physical comfort could encourage active transportation (Sun et al., 2020) beyond providing safety. It leads to reduction of motor vehicular functions and thereby energy consumption, increases human health and safety, and contribute in achieving many other sustainability goals (World Health Organisation, 2017). Therefore it is necessary to identify the significance of physical safety and comfort in the present concept of sustainability.

6.1 ANALYSIS OF UN SUSTAINABILITY CONCEPTS AND SIGNIFICANCE OF PHYSICAL SAFETY AND COMFORT

The United Nations (UN) is an internationally influential organisation (Novosadand Werker, 2019) and sustainability is a universally trending concept. The decisions and plans of the UN on sustainability makes significant global impact,

and therefore it is important to analyse the inclusion and significance of physical safety and comfort in the UN agenda on concept of sustainability to efficiently decrease the road accident rates.

Traffic death rate was a concern raised by the UN in developing the 2030 Agenda for Sustainable Development from the Millennium Achievement Goals, in 2015 (United Nations Development Programme, 2015). This Agenda targets to halve the road traffic deaths and injuries by 2020 (WHO, 2017). Accordingly, 'The Safe System approach' proposed by the World Health Organisation on controlling Road Traffic Injuries (WHO, 2017) states that roads should be designed to forgive human error. The Road Safety Technical Package of this approach proposes 06 effective strategies to reduce traffic crash impacts and contributes in achieving Sustainable Development Goal target 3.6 which is to halve the number of victims of road accidents, and target 11.2 which is to provide safe and affordable access to sustainable transport systems for all, while prioritising vulnerable groups (United Nations Development Programme, 2015). Strategies on 'Speed management' and 'Infrastructure Design and Improvement' would require the inclusion of physical safety and comfort factors though they have not been directly quoted.

Table 1, Sustainable Development Goals on urban development and human safety and comfort (United Nations Development Programme, 2015)

Goal No.	UN Sustainable Goals	Important aspects considered	Targets	
03	Good health and well-being	Ensure good health and well-being for all ages	3.6	By 2020, halve the number of global deaths and injuries from road traffic accidents
09	Industry, innovation and infrastructure	Establish strong infrastructure, promoting inclusive and sustainable industrialisation and foster innovation	9.1	Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all
11	Sustainable cities and communities	Promote sustainable cities and inclusive and safe human settlements	11.2	By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons

Considering the Sustainability Development Goals (SDG) proposed by the UN, only SDG 3, 9 and 11 address the issues relevant to the research problem. As could be noted from Table 1, only Sustainable Development Goals (SDG) 3 and 11 directly emphasise human safety and health, while SDG 9 emphasises a resilient and innovative infrastructure which indirectly ensures economic stability and human well-being. All three goals are influenced by multiple factors, but none directly highlights the inclusion of physical safety and comfort as an element of sustainable design of public realm.

'Save lives – A road safety technical package' (WHO, 2017) proposes a safe system approach based up on the Sweden's vision zero strategy (Kristianssen, Andersson, Belin, and Nilsen, 2018). This approach consists of various frameworks to a holistic assessment of road traffic injury risk factors and interventions (WHO, 2017). This approach emphasises, 'Education and information', 'Innovation', 'Monitoring, management and coordination', 'Data analysis, research and evaluation', 'Road rules and enforcement', and 'Licensing and registration' as key elements and identifies six major components and interventions (figure 3) to achieve the sustainability goal (WHO, 2017, p. 9). The intention of the approach is to establish safe roads through appropriate design.

Safety cannot be achieved through a single factor or a one way process, and needs a holistic approach of all the above mentioned key factors, and hence, it is important to confirm that the key factors address all relevant physical safety and comfort determinants. Enforcement of road rules is very important, and therefore physical safety and comfort should be included in the 'Road rules and enforcement' element. Rules and regulations are compulsory, yet in reality are easily disregarded and that is unidentified until any consequent calamities occur. Application of sustainability index tool at design stage could clearly depict a quantity identifying the impacts at design stages, preventing inefficient construction (Yigitcanlar, and Dur, 2010). Therefore it would be efficient to include the conformity of physical safety and comfort as an element of sustainability design index to achieve the sustainability goals effectively to ensure reduction of traffic crashes.

The infrastructure design and improvement of roads proposed by World Health Organisation (2017) through 'Save lives – A road safety technical package' proposes solutions that ensure physical safety and comfort, such as: providing safe road infrastructure, making safe road sides and intersections, implementing cycle lanes, etc. It also emphasises the need for assessing road safety strategy implementation efficiency; but does not address all the necessary components of roads in detail. Hence, ensuring physical safety and comfort as one of the key element of

development with detailed identification of the components of roads could efficiently contribute to reduction of road crashes.

Acronym	Component	Interventions
	Speed management	<ul style="list-style-type: none"> Establish and enforce speed limit laws nationwide, locally and in cities Build or modify roads which calm traffic, e.g. roundabouts, road narrowing, speed bumps, chicanes and rumble strips Require car makers to install new technologies, such as intelligent speed adaptation, to help drivers keep to speed limits
	Leadership on road safety	<ul style="list-style-type: none"> Create an agency to spearhead road safety Develop and fund a road safety strategy Evaluate the impact of road safety strategies Monitor road safety by strengthening data systems Raise awareness and public support through education and campaigns Provide safe infrastructure for all road users including sidewalks, safe crossings, refuges, overpasses and underpasses Put in place bicycle and motorcycle lanes
	Infrastructure design and improvement	<ul style="list-style-type: none"> Make the sides of roads safer by using clear zones, collapsible structures or barriers Design safer intersections Separate access roads from through-roads Prioritize people by putting in place vehicle-free zones Restrict traffic and speed in residential, commercial and school zones Provide better, safer routes for public transport
	Vehicle safety standards	<ul style="list-style-type: none"> Establish and enforce motor vehicle safety standard regulations related to: <ul style="list-style-type: none"> • seat-belts; • electronic stability control; • seat-belt anchorages; • pedestrian protection; and • frontal impact; • ISOFIX child restraint points • side impact; Establish and enforce regulations on motorcycle anti-lock braking and daytime running lights
	Enforcement of traffic laws	<ul style="list-style-type: none"> Establish and enforce laws at national, local and city levels on: <ul style="list-style-type: none"> • drinking and driving; • seat-belts; and • motorcycle helmets; • child restraints
	Survival after a crash	<ul style="list-style-type: none"> Develop organized and integrated prehospital and facility-based emergency care systems Train those who respond to crashes in basic emergency care Promote community first responder training

Figure 3, Save LIVES: six components and 22 interventions (World Health Organisation, 2017)

6.2 ANALYSIS OF UNECE SUSTAINABILITY CONCEPTS AND INCLUSION OF PHYSICAL SAFETY AND COMFORT

United Nations Economic Commission for Europe (UNECE) is a commission that offers regional framework to 56 European countries on elaboration and harmonisation of standards and conventions. The UNECE Sustainable Transport Division sets its focus on road safety based upon the United Nations 2011 Global Plan for the Decade of Action for Road Safety (UNECE, 2015). UNECE (2015) states that any safety strategy should harmoniously address the heterogenic users. The road system in Sweden is set as an example, as safety is prioritised over convenience and speed, in design and construction (UNECE, 2015). Yet ignorance of physical comfort of user could again lead to road accidents. For example, if the side walk surface finish is not smooth or well levelled, it could cause pedestrians to fall, which at adverse condition may lead to death. Therefore it is important to provide prominence to both physical safety and comfort to develop a sustainable design, which is not emphasised in the UNECE sustainability concept. The UNECE (2015) derived 11 goals from the five pillars of the UN Global Plan (Table 2) to formulate a strategy for the decade, to achieve road safety, and the main goal of reducing the road traffic injuries and deaths by 50%. None of the goals emphasise the importance of inclusion of physical safety and comfort in designing streets.

Road safety is primarily determined by regulations and its efficient enforcement. With increased globalisation and tourism, it is important that such regulations are set to universal standards in order for anyone from any part of the world to access the roads at any street in the world safely (UNECE, 2015). The UN conventions and agreements are formulated so as to ensure road safety, yet are not recognised or prioritised as other matters. However, the best acknowledged, and practiced universal tool is the ‘sustainability’ measure, which also does not emphasise the need for inclusion of physical safety and comfort as an assessment criteria.

Table 2, Summary of Global Plan 'Pillars' and Action Plan Goals (UNECE, 2015)

Five Pillars of UN Global Plan	11 Goals of the UNECE Action Plan
1. Road safety management	1. Boost political will and support government strategies
2. Safer road users	2. Protect vulnerable road users
	3. Turn road safety training, education and behaviour into knowledge management
	4. Raise awareness, fundraise and advocate for road safety
3. Safer roads and mobility	5. Make roads safer (including tunnels, rules, signs and signals)
	6. Make technologies work for safer mobility
4. Safer vehicles	7. Make vehicles safer
	8. Improve cargo safety

	9. Improve the safety of transporting dangerous goods
5. Post-crash response	10. Mitigate the impact of road crashes
	11. Learn from road crashes

In summarising, it can be stated that international concept on sustainability does not clearly prioritise the significance of physical safety and comfort with regard to urban planning or street design.

7. Significance of physical safety and comfort in the urban sustainability assessment tools

Sustainability Assessment (SA) is a scientific evaluation for decision making (Serenella Sala, Biagio Ciuffo, Peter Nijkamp, 2015). A range of sustainability measurement tools are used globally (figure 4). Among them, four most extensively used international urban sustainability assessment tools are considered in this analysis: Comprehensive Assessment System for Built Environment Efficiency (CASBEE), Green Building Index (GBI), Building Research Establishment Environmental Assessment Method (BREEAM) & Civil Engineering Environmental Quality Assessment & Award Scheme (CEEQUAL) by BRE, and Leadership in Energy and Environmental Design (LEED) for Cities and communities (Kaurand Garg, 2019) based on the consideration of urban context and popularity in usage.

22 countries and 59 tools



Figure 4, Summary of Global Survey of Urban Sustainability Rating Tools (Criterion Planners – a Global Survey of Urban Sustainability Rating Tools, 2014)

7.1 REVIEW ON SUSTAINABILITY ASSESSMENT TOOLS

Table 3, Review of Sustainability Assessment Tools, (Author, 2022)

Sustainability assessment tools	Review on inclusion of physical safety and comfort
Comprehensive Assessment System for Built Environment Efficiency (CASBEE)	CASBEE is a tool developed by the Japan Sustainable Building Association with the support of Ministry of Land, Infrastructure, Transport and Tourism and announced in 2003 to evaluate the environmental performance rooted from Social, Environmental and Economic aspects (Japan Sustainable Building Association, 2014). "CASBEE-City" tool is used to evaluate the environmental performance of cities. No concern is provided with regard to physical safety and comfort.
Green Building Index (GBI)	GBI is an environmental rating system developed by the Malaysian Institute of Architects based on six core criteria: Climate, Energy and Water, Ecology and Environment, Community Planning and Design, Transportation and Connectivity, Building and Resources, and Business and

	Innovation (GSB, 2017). Designed to address the environmental, social and economic issues. In this tool as well, the physical safety and comfort aspect is ignored.
Building Research Establishment Environmental Assessment Method (BREEAM)- The Civil Engineering Environmental Quality Assessment & Award Scheme (CEEQUAL)	BREEAM, first launched in 1990, is developed to assess the environmental, social and economic sustainability performance of master planning projects, infrastructure and buildings (Building Research Establishment Ltd 2021, 2020). The BREEAM sustainability standards are evaluated under nine categories: Energy, Waste, Water, Materials, Health and Wellbeing, Transport, Pollution, Land Use & Ecology, and Management (BRE group, 2019). CEEQUAL sustainability rating scheme for infrastructure by the BRE includes public realm assessment. Physical safety and comfort are not included in the criteria of assessment, or in the standards; though health and well-being is assessed through the above mentioned nine categories, none address the problems on physical safety and comfort (BRE Group, 2019).
Leadership in Energy and Environmental Design (LEED) for cities and communities	LEED is an American sustainability rating system, which commenced as a green building rating system (Green Building Council, 2019). LEED for Cities and Communities assists the planners to design and evaluate natural systems, energy and transportation elements etc. of the cities aligned with the UN Sustainable Development Goals (The U.S. Green Building Council, 2019). The LEED sustainability progress tracking objectives as per the U.S. Green Building Council (2019) does not emphasize the requirement of physical safety and comfort.
International Road Assessment Programme (iRAP)	The tools developed by the International Road Assessment Programme (iRAP) are based on achieving the SDG goal 3 and 4(International Road Assessment Programme [iRAP], 2021). Accordingly they are designed for street risk mapping, star rating, and policy and performance tracking to prevent injuries and deaths (iRAP, 2021). As per the iRAP (2021), the star rating tool provides a measure of the safety of roads for different user categories. The target through the process is to improve the road qualities in order to achieve more stars that depict the improved safety levels of streets. The road safety toolkit by iRAP (2021) is used to identify the causes and prevention of road crashes. However it is not established as a ‘sustainability status’ measurement tool, but a tool to achieve SDG 3 and 4. Therefore this tool is not prioritised among the developing countries such as Sri Lanka.

From the above analysis (table 3), it can be stated that all the sustainability measurement tools around the globe are based on the UN Sustainable Development Goals, which does not underscore the significance of physical safety and comfort, and are focused typically on the ‘Green concept’ of buildings, rather than open public realm (table 4). Street assessment tools such as ‘International Road Assessment Programme: Road Safety Toolkit’ contribute in identifying causes of street safety threats and rectifying accordingly (International Road Assessment Programme, 2021). Global Designing Cities Initiative (2016) street Design Guidelines are available to ensure street safety and comfort for different street elements. However, such design assessment and guideline tools are not efficiently utilised or executed as they do not provide a global rating for ubiquitous concept such as ‘sustainability’, though they contribute in achieving the Sustainable Development Goals (Global Designing Cities Initiative, 2016). Thus, it is vital to incorporate physical safety and comfort factors of streets as a criteria of tools that are universally identified as public realm sustainability rating tools.

Table 4, Sustainability definition and assessment tool conclusion table, (Author, 2021).

Problem	Action / Assessment tool		Target
	Plan / Indicator	Outcome / results	
Higher number of road accident injuries and increasing road	United Nations Sustainable Development Goal		
	death rate due to traffic injuries in Colombo	Has reduced only by 10% from 2018 – 2019. Not achieved.	3.6: ‘death rate due to traffic injuries’, and that of the target
	Proportion of population that has convenient access to public	Not yet recorded or assessed either locally	11.2: ‘Proportion of population that has convenient access to

accident deaths	transport, by sex, age and persons with disabilities in Colombo	or globally. Therefore result is not known.	public transport, by sex, age and persons with disabilities'
	Sustainability Assessment tools		
	Comprehensive Assessment System for Built Environment Efficiency (CASBEE)		"CASBEE-City" tool to evaluate the environmental performance of cities
	Green Building Index (GBI)		Environmental rating system to address the environmental, social and economic issues
	Sustainability assessment tools by BRE: Building Research Establishment Environmental Assessment Method (BREEAM) and CEEQUAL sustainability rating scheme for infrastructure		Assess the environmental, social and economic sustainability performance of master planning projects, infrastructure and buildings. CEEQUAL sustainability rating scheme for infrastructure by the BRE includes public realm assessment
	Leadership in Energy and Environmental Design (LEED) for Cities and Communities		LEED for Cities and Communities assists the planners to design and evaluate natural systems, energy and transportation elements etc. of the cities
	Street safety assessment tools		
	International Road Assessment Programme (iRAP)		Improve the level of road safety in order to achieve SDG 3 and 4, through assessment of road design using different tools to identify the cause of risk and suggest improvements accordingly

7.2 OVERVIEW ON THE CONCEPT OF SUSTAINABILITY IN SRI LANKA WITH REGARD TO PHYSICAL SAFETY AND COMFORT OF USERS OF STREETS

The Sustainability Development Goals in Sri Lanka are entirely based upon the UN Sustainability Development goals (United Nations Statistics Division, 2018, Department of Census and Statistics, 2018). Accordingly, Department of Census and Statistics (2018) states that the indicator of SDG 3.6 of the UN is the 'death rate due to traffic injuries' (figure 5), and that of the SDG 11.2 is the 'Proportion of population that has convenient access to public transport, by sex, age and persons with disabilities'. Both the indicators are primarily determined by the physical safety and comfort level, which accentuates the need for inclusion of physical safety and comfort as an element of sustainability rating. As summarised in the literature analysis, the SDG 3.6 is not achieved by Sri Lanka, and instead a very critical state is approaching considering the increase in the number of road accident deaths (Department of Census and Statistics, 2018).

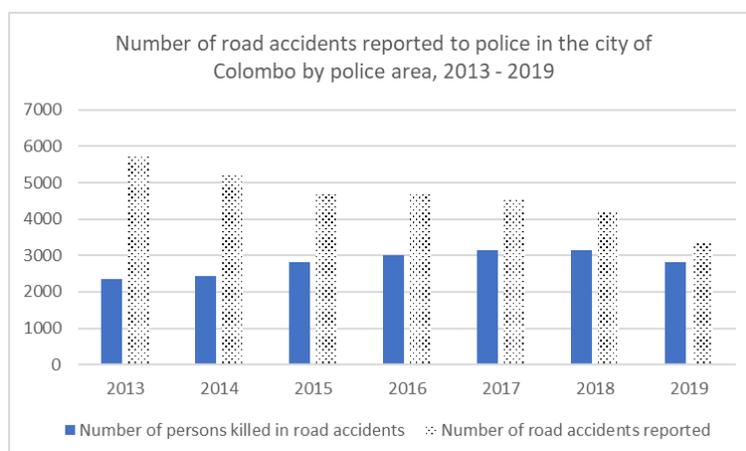


Figure 5, Number of road accidents reported to police in the city of Colombo by police area, 2013 – 2019 (Author’s representation of the data from Department of Census and Statistics, 2018)

As per the report by United Nations, (2018), it is clear that, SDG 11.2 aims primarily towards implementing modern and efficient public transport systems rather than ensuring physical safety and comfort. It is considered a tier 2 indicator for which the criteria is defined clearly, but the partner countries do not assess and produce regular reports. Sri Lanka does not even hold a comprehensive tool to estimate the sustainability of transport system (Bandara, s, 2017). The Department of Census and Statistics (2018) has not published any data on this indicator of the UN SDG goal 11.2 and neither has the UN SDG tracker (Out World In Data, 2021). Globally only 50% of the population has convenient access to public transport (Majeed, 2021). In Sri Lanka, since 2000 the private vehicular mode had tripled due to lack of convenience of public transport, though 57% of total passengers depend on public transport (Majeed, 2021). Therefore, it essential to take effective actions to augment the quality of public transport conforming to required minimum physical safety and comfort levels to achieve sustainability.

In addition, 'Vision 2025: Sri Lanka's Path to Prosperity' launched by the government of Sri Lanka is planning to elevate the country's standard of living including concerns on infrastructure and road developments (World Bank Group, 2017). But the target of the plans is based upon the economic augmentation rather than any other factors. Therefore, as in any other global sustainability assessment tool discussed above, the physical safety and comfort is disregarded, resulting in a high annual road crash deaths per capita, which is almost double that of any other high-income country (The World bank, 2020).

8. Conclusion

Road accidents are a major global problem that requires an immediate and effective solution. Through years of development all the actions taken to solve the problem on road accidents are focussed on rectifying and amending the laws and regulations on vehicular speed, road signage, charging fines from traffic offenders etc. to control user behaviour, which have turned out to be ineffective as could be observed with the increasing rate of traffic fatalities. Regardless of the actions of users, roads have to be designed to prevent mishaps, because controlling the diverse user behaviour is beyond the capacity of authorities. Accordingly, designing streets ensuring physical safety and comfort becomes vital. Considering sustainability as being one of the prioritised and best implemented global concepts, it is recommended to incorporate physical safety and comfort as a key component of sustainability for more effective results. The 'pillars' of sustainability, which are Environmental, Economic, Social and Institutional factors, do not highlight physical safety and comfort of users. Most of the globally practiced sustainability measurement tools also focus primarily on 'green' concept of buildings that emphasise on thermal comfort and climatology rather than ensuring user physical safety and comfort with regard to ergonomics and anthropometrics in public realm.

Considering the international sustainability concepts and assessment tools, it is evident through the review that none of the tools that endorse 'sustainability status' have integrated the physical safety and comfort as an element. Therefore, the analysis concludes that in order to reduce street accidents, physical safety and comfort should be included as a criteria in the formulation of any sustainability assessment tool, which is well-established and prioritised internationally by all designers and governing authorities. It is recommended to include physical safety and comfort as a criteria of assessment of sustainability as it contributes to the element being prioritised in urban planning, and thereby reducing rate of accidents with development of safe and comfortable streets. The summary of the review further contributes for decision making by urban developers, and research by scholars with regard to urban sustainability assessment tools and criteria analysis.

9. Acknowledgements

This work is supported by the Accelerating Higher Education Expansion and Development (AHEAD)- DOR Grant affiliation with Ministry of Higher Education & University Grants Commission and funded by the World Bank.

10. Reference

- Ahmed-Kristensen, S., & Stavrakos, S.K. 2012. Definition of comfort in design and key aspects- A literature review. In *Proceedings of NordDesign Conference 2012* Aalborg University, Center for Industrial Production.
- Bandara, S. 2017. 'Sustainable Transport Initiatives in Sri Lanka'. *Capacity Building Workshop on Sustainable, Urban Transport Index* [online]. Available at : https://www.unescap.org/sites/default/files/11.%20Sus%20Transport%20Initaitives%20in%20Sri%20Lanka-Prof.Saman_.pdf (Accessed: 17 June 2021)
- Bigliardi, B., & Filippelli, S. 2022. Chapter 4 - 'Factors affecting the growth of academic oriented spin-offs', Editor(s): Charis M. Galanakis, *Innovation Strategies in the Food Industry* (Second Edition), Academic, Pages 53-72, ISBN 9780323852036, <https://doi.org/10.1016/B978-0-323-85203-6.00012-8>. (<https://www.sciencedirect.com/science/article/pii/B9780323852036000128>)
- BRE group. 2019. *Standards* [online]. Available at : <https://www.bregroup.com/services/standards/> (Accessed: 18 June 2021)

- BRE Group. 2019. *Version 5 – CEEQUAL*, CEEQUAL - The Evidence-Based Sustainability Assessment, Rating and Awards Scheme for Civil Engineering, Infrastructure, Landscaping and Public Realm Projects [online]. Available at : <https://www.ceequal.com/version-5/> (Accessed: 18 June 2021)
- Building Research Establishment Ltd 2021. 2020. *BREEAM* [online]. Available at : <https://www.breeam.com/discover/why-choose-breeam/> (Accessed: 18 June 2021)
- Burford G, Hoover E, Velasco I, Janoušková S, Jimenez A, Piggot G, Podger D, Harder MK., 2013. Bringing the “Missing Pillar” into Sustainable Development Goals: Towards Intersubjective Values-Based Indicators: Sustainability. 2013; 5(7):3035-3059 [online]. Available at: <https://doi.org/10.3390/su5073035> (Accessed: 17 June 2021)
- Criterion Planners – a Global Survey of Urban Sustainability Rating Tools, 2014 [online]. Available at: http://crit.com/wp-content/uploads/2014/11/criterion_planners_sustainability_ratings_tool.pdf (Accessed: 17 June 2021)
- Department of Census and Statistics, 2019. 'Number of road accidents, 2013 – 2019' [online]. Available at: <http://www.statistics.gov.lk/abstract2020/CHAP7> (Accessed: 17 June 2021)
- Department of Census and Statistics, 2018. 'Sri Lanka, Sustainable Development Goals'. Department of Census and Statistics, Sri Lanka [online]. Available at: http://www.statistics.gov.lk/sdg/index.php/sdg/page/SDG_Goals (Accessed: 17 June 2021)
- Díaz-López, C., Carpio, M., Martín-Morales, M., & Zamorano, M., 2019. Analysis of the scientific evolution of building sustainability assessment methods. Sustainable Cities and Society, 101610. doi:10.1016/j.scs.2019.101610
- Gasparatos, A., El-Haram, M., & Horner, M., 2009. Assessing the sustainability of the UK society using thermodynamic concepts: Part 1. *Renewable and Sustainable Energy Reviews*, 13(5), 1074–1081. doi:10.1016/j.rser.2008.03.004
- Global Design Cities Initiative, 2016. 'Global Street Design Guide', ISBN: 978-1-61091-494-9, [online]. Available at: <https://globaldesigningcities.org/wp-content/uploads/guides/global-street-design-guide.pdf> (Accessed: 18 October 2021)
- Green Building Council, 2019. 'About: Brand | U.S. Green Building Council. LEED' [online]. Available at: <https://www.usgbc.org/about/brand> (Accessed: 17 June 2021)
- Green Building Index Sdn Bhd, 2017. 'GBI Assessment Criteria for Township Version 2.0 Pilot' [online]. Available at: <https://www.greenbuildingindex.org/Files/Resources/GBI%20Tools/GBI%20Township%20Tool%20V2.0.pdf> (Accessed: 17 June 2021)
- Harsimran, K., Pushplata, G. 2019, 'Urban sustainability assessment tools: A review, *Journal of Cleaner Production*', Volume 210, 2019, Pages 146-158, ISSN 0959-6526, [online]. Available at: <https://doi.org/10.1016/j.jclepro.2018.11.009>. (Accessed: 17 June 2021)
- International Road Assessment Programme, 2021. 'Road Safety Toolkit' [online]. Available at: <http://toolkit.irap.org/> (Accessed: 16 October 2021)
- Japan Sustainable Building Association, 2014. CASBEE-City. '6.1 Comprehensive Assessment System for Built Environment Efficiency' [online]. Available at: https://www.ibec.or.jp/CASBEE/cas_city/casbee_city2013.htm (Accessed: 17 June 2021)
- Khder, Hazhar & Mousavi, M. & Khan, Tareef, 2016. Impact of Street's Physical Elements on Walkability: a Case of Mawlawi Street in Sulaymaniyah, Iraq. *International Journal of Built Environment and Sustainability*. 3. 10.11113/ijbes.v3.n1.106.
- Kristianssen, A.-C., Andersson, R., Belin, M.-Å., & Nilsen, P., 2018. Swedish Vision Zero policies for safety – A comparative policy content analysis. *Safety Science*, 103, 260–269. Available at: <https://www.sciencedirect.com/science/article/pii/S0925753517309013> (Accessed: 17 June 2021)
- MAJEED, S. A. J. A. A. A., 2021. 'Sustainable Development Goal (SDG 11): Sustainable Cities and Communities - Engineers must act fast to get it right'. The Institution of Engineers Sri Lanka [online]. Available at: <https://iesl.lk/SLEN/54/SDG.php> (Accessed: 17 June 2021)
- Michaela F. P., 2015. 'Great Asian Streets Symposium: Asian Urban Places'. *Journal of Landscape Architecture*, 10:2, 99, DOI: 10.1080/18626033.2015.1058582
- National Association of City Transportation Officials, 2017. USA. Urban Street Design Guide [online]. Available at: <https://nacto.org/publication/urban-street-design-guide/> (Accessed: 16 October 2021)
- National Institute of Building Sciences, 2021. 'Provide Comfortable Environments | WBDG - Whole Building Design Guide', National Institute of Building Sciences [online]. Available at: <https://www.wbdg.org/design-objectives/productive/provide-comfortable-environments> (Accessed: 17 June 2021)
- National Research Council, 2011. "4 Sustainability Assessment and Management: Process, Tools, and Indicators." Sustainability and the U.S. EPA. Washington, DC: The National Academies Press. doi: 10.17226/13152.
- Novosad, P., Werker, E., 2019. 'Who runs the international system? Nationality and leadership in the United Nations Secretariat. *Rev Int Organ*' [online]14, 1–33. Available at: <https://doi.org/10.1007/s11558-017-9294-z> (Accessed 10 October 2021)
- Our World In Data, 2021. 'Goal 11: Sustainable Cities and Communities - SDG Tracker'. Our World in Data [online]. Available at: <https://sdg-tracker.org/cities> (Accessed: 17 June 2021)
- Perera, Clifford, 2016. 'Legal aspects of motor traffic trauma in Sri Lanka, *Egyptian Journal of Forensic Sciences*', Volume 6, Issue 4, 2016, Pages 342-346, ISSN 2090-536X, [online]. <https://doi.org/10.1016/j.ejfs.2016.02.001>. Available at: <https://www.sciencedirect.com/science/article/pii/S2090536X16000174> (Accessed: 17 June 2021)
- Serenella, S., Biagio, C., Peter, N 2015. 'A systemic framework for sustainability assessment', *Ecological Economics*, Volume 119, Pages 314-325, ISSN 0921-8009, [online]. <https://doi.org/10.1016/j.ecolecon.2015.09.015>. <https://www.sciencedirect.com/science/article/pii/S0921800915003821> (Accessed: 17 June 2021)
- Serkan Yıldız, Serkan Kivrak, Arzuhan Burcu Gültekin, Gökhan Arslan, 2020. 'Built environment design - social sustainability relation in urban renewal', *Sustainable Cities and Society*, Volume 60, (2020), 102173, ISSN 2210-6707,[online]. <https://doi.org/10.1016/j.scs.2020.102173>. Available at: <https://www.sciencedirect.com/science/article/pii/S2210670720301608> (Accessed: 17 June 2021)
- Sun S., Q. Zhou, S. Lal, H. Xu, K. Goh & Y. D. Wong 2020. 'Quantifying performance of sheltered link-way facility in Singapore using human-centric indicators', *International Journal of Urban Sustainable Development*, DOI: 10.1080/19463138.2020.1858422.
- The World Bank, 2020. 'Delivering Road Safety in Sri Lanka'. Leadership Priorities and Initiatives to 2030, [online]. Available at: <https://openknowledge.worldbank.org/bitstream/handle/10986/33341/ROAD%20SAFETY%20IN%20SRI%20LANKA.pdf?sequence=1&isAllowed=y> (Accessed: 17 June 2021)
- The World Bank, 2020b. Urban Development Overview. World Bank [online]. Available at: <https://www.worldbank.org/en/topic/urbandevelopment/overview> (Accessed: 16 October 2021)

- United Nations Development Programme. 2015. '*Sustainable Development Goals | United Nations Development Programme*' [online]. Available at: https://www.undp.org/sustainable-development-goals?utm_source=EN&utm_medium=GSR&utm_content=US_UNDP_PaidSearch_Brand_English&utm_campaign=CENTRAL&c_src=CENTRAL&c_src2=GSR&gclid=CjwKCAjwoNuGBhA8EiwAFxomA-L4UR8FYq5NKh2jQxtB3GEsxsBa07cQrt_CzdNrOnEJMvnjWlgBoCpZYQAvD_BwE (Accessed: 17 June 2021)
- United Nations Economic Commission for Europe. 2015 '*Together with UNECE on the road to safety: cutting road traffic deaths and injuries in half by 2020*'. Geneva. [online]. Available at : <https://euagenda.eu/upload/publications/untitled-62401-ea.pdf>
- United Nations Statistics Division. 2018. '*Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development*'. United Nations Statistics Division, [online]. Available at : https://unstats.un.org/sdgs/indicators/Global%20Indicator%20Framework%20after%20refinement_Eng.pdf (Accessed: 17 June 2021)
- United Nations. 1987. '*Sustainability*' [online]. Available at: <https://www.un.org/en/academic-impact/sustainability> (Accessed: 17 June 2021)
- United Nations. (n.d.). '*Sustainable transport*', Sustainable Development Knowledge Platform [online]. Available at: <https://sustainabledevelopment.un.org/topics/sustainabletransport> (Accessed: 17 June 2021)
- United Nations. 2018. '*Voluntary National Review 2018: Sri Lanka : Sustainable Development Knowledge Platform*'. Sustainable Development Goals, Knowledge Platform [online]. Available at: <https://sustainabledevelopment.un.org/memberstates/srilanka> (Accessed: 17 June 2021)
- United Nations. 2002. '*World Summit on Sustainable Development*'. United Nations Sustainable Development Goals Knowledge Platform [online]. Available at: https://www.un.org/ga/search/view_doc.asp?symbol=A/C.2/57/L.83&Lang=E (Accessed: 17 June 2021)
- U.S. Green Building Council. 2019. '*LEED for Cities and Communities*' | U.S. Green Building Council [online]. Available at : <https://www.usgbc.org/leed/rating-systems/leed-for-cities> (Accessed: 17 June 2021)
- William W. H. 1952-1953. 'Prevention and Reduction of Injuries in Traffic Collisions', 43 J. Crim. L. Criminology & Police Sci. 515 [online]. Available at: <https://scholarlycommons.law.northwestern.edu/cgi/viewcontent.cgi?article=4056&context=jclc> (Accessed: 16 October 2021)
- World Bank Group. 2017. '*Vision 2025: Sri Lanka's Path to Prosperity*', World Bank [online]. Available at : <https://www.worldbank.org/en/news/feature/2017/10/17/vision-2025-sri-lankas-path-to-prosperity> (Accessed: 17 June 2021)
- World Health Organization. 2020. '*Road traffic injuries - Fact Sheet*' [online]. Available at: <https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries> (Accessed: 17 June 2021)
- World Health Organization, 2017. '*Save lives: a road safety technical package*'. World Health Organization, License: CC BY-NC-SA 3.0 IGO , [online]. Available at: <https://apps.who.int/iris/handle/10665/255199> . (Accessed: 17 June 2021)
- World Health Organization 2018. '*Global Status Report 2018*'. World Health Organization. ISBN 978-92-4-156568-4 [online]. Available at: <https://www.who.int/publications/i/item/9789241565684> (Accessed: 17 June 2021)
- Yigitcanlar, T., & Dur, F., 2010. Developing a Sustainability Assessment Model: The Sustainable Infrastructure, Land-Use, Environment and Transport Model. Sustainability, 2(1), 321–340. doi:10.3390/su2010321