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Review

A Comprehensive Study on the Sustainable Transportation System in India and Lessons to Be Learned from Other Developing Nations

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Abstract: The wheel was the first form of transportation developed by early people. Increasing population, longer distances, and shorter travel times need more cheap, faster modes of transportation. Environmental issues were never taken into account when choosing the most cost-effective mode of public transportation. Consequently, in the face of global pollution and warming restrictions, all stakeholders choose modes of transportation with little environmental impact. This has led to the development of sustainable transportation infrastructure, particularly in a country as rapidly developing as India. This paper examines the present situation, legislation, and grading systems for sustainable transportation in India and other developing nations. Furthermore, comparisons of India with developing nations of various continents in different aspects are also present. The difference in cost between a private car and a public vehicle indicates which form of transportation should be chosen. The challenges linked with urban and rural Indian roadways are explored, as well as their respective solutions. In order to accomplish sustainable transportation, traffic density and driver conduct are also considered. This study emphasises that sustainability is not just achieved through the use of cleaner fuel or the modification of road materials, although these are vital. Road design, regulatory changes, psychological behaviour, and transit safety are also crucial.

Keywords: sustainable transportation; Indian roads; vehicles

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1. Introduction

The twenty-first century brought unprecedented urbanisation and economic growth for developing countries such as India, due to the industrial and technological revolutions which were necessary for better standards of living for the people. According to United Nations Sustainable Habitat Development Goals (SDGs) for cities, fifty percent of the global population resides in urban areas, and this proportion is predicted to expand by 2/3 by 2050 [1]. As a result of their influence on investment, consumption and innovation, cities are regarded as knowledge workers for the world. Cities aid in economic growth, urban development, prosperity, and an improved state of living. Sustainability as a term was coined in 1987 during the United Nations Brundtland Commission, which defined it as "*meeting the needs of the present without compromising the ability of future generations to meet their own needs*" [2]. After 1987, John Elkington coined the term "triple-bottom-line" for sustainability in 1994, indicating that all companies should consider three factors: first, they should not only care about profit and loss; second, the social responsibility of their value chains should be calculated; and third, the environmental impact of their companies should be measured [3]. In the year 2001, the United Nations (UN) requested a 4-year-long

investigation which is known as the "Millennium Ecosystem Assessment" which found out how humans have deteriorated the eco-system but benefitted the economy. It further found that bad ecosystems are going to harm humans and society, and certain policy changes need to be made to counter that [3]. Sustainable development today has a framework as defined by various reports, which dictates the world should demonstrate big changes that will help curb the CO_2 emissions of the world and keep the temperature under two degrees Celsius. It also helps nations and businesses to achieve sustainable goals and encourages them by giving certain rewards such as the B-Corp movement, the Rainforest Alliance, etc. [3–6].

There are several countries in the world's emerging regions that are looking for ways to advance their economies, but climate change poses a growing obstacle. Therefore, steps should be adopted for minimal environmental impact, and concrete efforts should be made to attain and strive for progress [2]. There must be a symbiosis between three fundamental goals: economic growth, social inclusion, and environmental protection. Furthermore, alleviating poverty throughout its many dimensions is crucial for long-term development [7].

Since the mid-twentieth century, anthropogenic activities have been the leading cause of greenhouse gas (GHG) emissions and global warming [8,9]. Studies on climate change adaptation and mitigation strategies show that currently deployed measures are not enough to prevent the disastrous consequences of climate change [10]. As a result of global warming, the atmosphere has already begun to suffer observable effects. Many natural phenomena have shifted as a result of global warming, including the retreat of glaciers, the earlier melting of river and lake ice, and the earlier emergence of spring flowers. Sea ice loss, accelerated rising sea levels, and prolonged, more intense heat waves are just a few of the repercussions projected by experts as a consequence of global climate change. It is believed by scientists that human activities generating greenhouse gases will continue to be the fundamental reason of the continuous warming of planet in the foreseeable future [11].

The Intergovernmental Panel on Climate Change (IPCC), which includes over 1300 scientists from the US and other countries, projects a rise of temperature between 2.5 and 10 degrees Fahrenheit during the next century. The IPCC predicts that the severity of climate change's effects on different locations would vary over time and according to the ability of different social and environmental processes to buffer or adapt to the phenomenon [11,12]. Instead of enhancing bioenergy production without land use change emission, an equal carbon price should be applied to terrestrial carbon along with fossil and industrial carbon, deforestation can slow down or even reverse [12]. Such a measure would lead to a situation where the world can be stopped from reaching 450–550 ppmv (parts per million by volume) CO_2-eq levels [13]. The transportation sector accounts for about 24% of direct CO_2 emissions from fuel consumption all around the world [14].

Transportation has been classified into distinct categories based on varying definitions. The first classification on the basis of the surface point of view is land transport, air transport, water transport, etc. [15]. The second category is the means of transportation, which includes human porters, animal transport, roadways, civil aviation, railroads, waterways, conveyor transport, cable, ropeway and pipelines [16]. As per the energy used, vehicles are classified into solar energy, atomic energy, petrol and diesel energy, human energy, animal energy, etc. [15]. Classification is based on the degree of freedom, and one-degree movement includes railways and pipelines where the vehicles move along a line. Two-degree movement vehicles can move laterally and in a line such as boats, highway vehicles, etc., while three-degree movement vehicles can move longitudinally, vertically, and laterally such as aircraft, submarines etc. [15]. Based on the service provided transportation is categorised into passenger and freight. Based on ownership it is classified into own or foreign [15,16]. The transportation system is organised into four sections, control structures, terminal, vehicle, and way, and vehicles that ensure the proper functioning of the system [16]. What we call "Way" is the area set aside for vehicular and pedestrian traffic.

A transportation route can be an elementary indicative virtual trajectory determined for the transportation, or it can be a materialised, well-defined necessary transit facility such as a railroad, road, or pipeline. The vehicle is the piece of machinery that enables

the transportation of both humans (drivers and passengers) and goods. However, with pipeline transport, there is no vehicle in the conventional meaning of the word, and the moving power is supplied directly to the mass being moved. Vehicle loading or unloading operations between the transport system and the surrounding environment are best performed at terminals, stations, and stops. They might be the starting or ending places of a journey or hubs through which people or goods are transferred. The system's ability to freely move around in space raises the stakes for maintaining order. Pipelines and railroads, for instance, possess only one degree of freedom because of the inherent linearity of their guideways. Roads and rivers possess two degrees of freedom because they travel over a surface, necessitating the idea of regulations for moving vehicles to prevent the contradictory interferences between them and the surrounding guideways as much as feasible [16]. Figure 1 is the visual representation of the sub-division of the transportation systems.

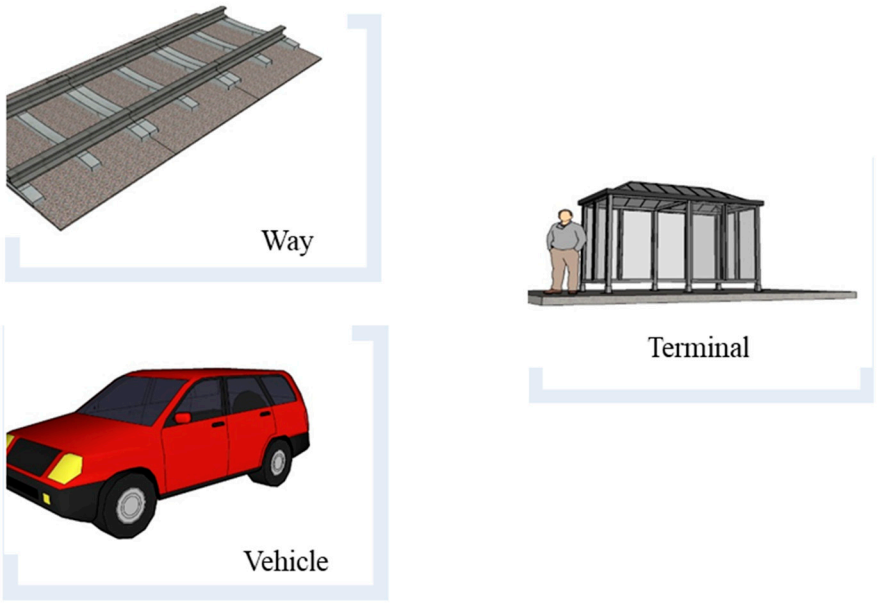

Figure 1. Sub-division of the transportation systems.

Vehicle design, together with ergonomics and other transportation-related product design, is referred to as transportation design. The existence and growth of transport design concepts, their place in the design process, and the articulation of their content, form, and function are at the heart of the issue [17]. Defining customer requirements, setting target specifications, generating and picking designs, setting final specifications, preparing objects, economic analysis, benchmarking competing items, modelling, and prototyping are required to generate a design concept [17]. In the absence of access to all-weather roads, half a billion people are still living in poverty, and an estimated one in six women worldwide are not looking for jobs in transit out of fear of harassment. It was reported that road accidents kill 3700 people and there are about 50,000 accidents a day [18]. In addition to contributing 16% of global greenhouse gas emissions, the transportation industry also generates daily pollution expenses in the multi-million dollar range [18]. Several research articles have been published on vehicular emissions and energy consumption as two major obstacles to achieving sustainable transport systems [19]. Yet apart from these two, there are other things which are even more important, one being road design, and the second is driver's behaviour which both causes accidents and loss of life globally [20,21]. Worldwide average annual growth for vehicles is 3% between the period of 1990 to 2015 [22]. There was a 5.89% growth in vehicle registration for the year 2022. Some developing countries such as India, China, Indonesia, Pakistan, Brazil, etc., have a growth average of 1.8% annually, while some others have 8.6% [22].

Road transport constituted 90.1% of the total emissions in the year 2014 amongst all the transport sectors in India, which was one of the recorded highs in the decade [22,23]. Figure 2 shows the emissions between different categories of transportation for the year 2014 [22,23]. A reimagining of the transportation system is necessary, and this can be accomplished only through the use of environmentally friendly practices. The term "sustainable transportation" was used to describe an approach to transportation expansion that would be good for the planet and society at large [24]. The restricted definition of sustainable transport emphasises environmental concerns and the depletion of resources. The broader meaning emphasises social and economic benefit [25]. In the rest of the work, Section 2 deals with the scenarios of sustainable transportation in developing nations such as Rwanda, Jordan, Palestine, India, etc. These countries were selected based on their similarity with India in terms of policy, transport behaviour and belonging to various areas of the world. The next part of the paper deals with the urban and rural road networks of India, their conditions, challenges faced and others, while Section 4 analyses the effects of traffic density and driver's behaviour on sustainable transportation achieving goals. The final two sections of the paper have a comparison of the green rating systems of India with other countries' rating systems and a highlight of the challenges and possible solutions that will help us to achieve a better sustainable method for transportation.

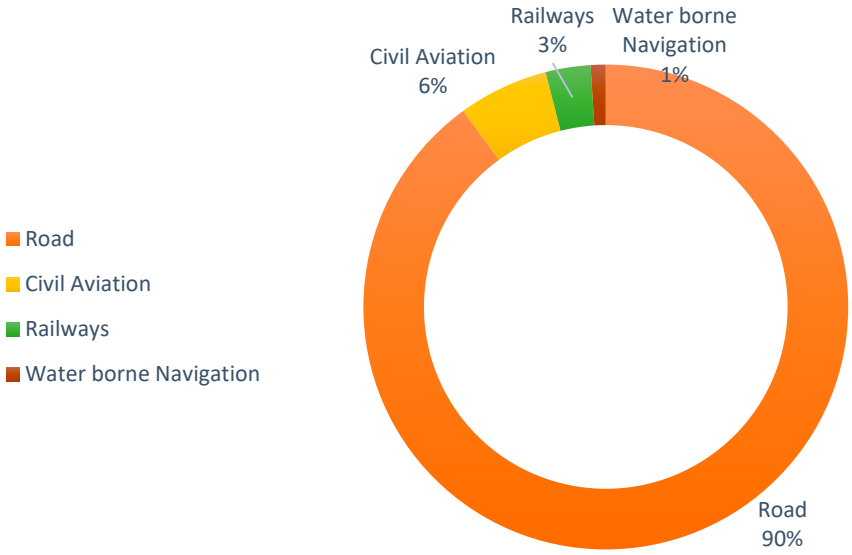

Figure 2. Pollutant emissions by various transportation sectors of India [23].

2. Sustainable Transportation Scenario in Developing Nations

Sustainable transportation is very important because such a system minimises traffic congestion and improves air quality, while reducing poverty and bringing economic prosperity [26]. In the absence of steps to ensure environment protection, rapid growth in motorisation in developing countries is taking place. Developing countries face a major challenge in balancing the demand for personal mobility and mitigating the high economic, environmental, and social costs of motorisation [27]. Therefore, defining policies that resolve high-priority socio-economic development problems while reducing the environmental and social costs of owning and using vehicles is a crucial challenge for developing countries [28]. Developing countries take ideas and learn from the plans and experiences of developed countries to create environmentally sustainable transportation technologies and policies [28]. Transportation sustainability must be factored into the development of long-term plans, and vehicles must play a central part in these plans. They play a central role in achieving sustainability, which may stand alone or complement the national development plans or master plans already that are prepared [28]. The study for this section has been based on a few case studies of different developing countries, conducted by various authors giving a better understanding of the sustainability approach taken by India.

Trade and transport facilitation is the title of a report published by the Jordanian Ministry of Transport. It states, "To solidify the socio-economic development and regional role of Jordan in transport and trade facilitation by cultivating dynamic and sustainable trade practises and by developing a multi-modal transport sector that is characterised by its operational performance, openness, and the policies and laws that govern it" [29]. A collection of interconnected and complementary strategies related to sustainable transport has been proposed in the National Transport Strategy of 2018. These include strategies related to measures to monitor pollutant emissions and GHGs based on state-of-the-art technologies including the development and rollout of a revamped bus network and services, the establishment and compliance of minimum vehicle standards to improve safety and quality standards, the enhancement of vehicle inspection procedures, the reduction of the operating age of vehicles, and more [30].

The Rwanda Strategic Master Plan for Transport was released by the Rwanda Development Agency for Transport in the year 2012. The strategic vision for this strategy, which offered guidelines for the implementation of integrated medium- and long-term land transport programs for the next 10 years, was established with pillars related to the sustainability of transport, namely, inter alia, the economic pillar, taking into account the implementation of a transport system that promotes sustainable economic activity. The study of the plan showed it aimed at providing a planning direction for transport issues to cover the organisation of the transport sector, as well as services and transportation infrastructure provision, to take a long-term view of the future transport system and to define programs and initiatives that safeguard services and transport infrastructure. The legitimacy of the existing system is also important, as well as providing a viable framework for the future system [31].

The Government of Jamaica mandated the Jamaica Planning Institute to prepare a National Development Plan (NDP) to allow Jamaica to achieve the status of a developed country by 2030. A wide variety of interrelated economic, environmental, and social factors were considered in the preparation of the strategy. The programme carefully considered the unique challenges presented by Jamaica's transportation system. The vision for transportation in Jamaica was defined and the main priorities, objectives, and strategies for the sector were decided by the government. Following the SWOT strategic evaluation approach, the Sector Strategy for Transport was structured. The major key goal of the Jamaica Transport Sector Strategy is to achieve a sustainable system of road transport that serves the country's economic and social needs [32]. Table 1 below analyses the case research of the three developing countries.

The measure for network data envelopment analysis (DEA) was used in a case study in India's neighbouring country of China to organise the three device components of parallel structure, allocation of common input across subsystems, and integration of undesired output. Mathematical operation differentiates the effectiveness of China's regional inland transport systems from 2006 to 2015, as this study shows [33]. In 2011 with 623.3 million metric tonnes of CO_2 emissions from transportation, China ranked second worldwide. In this respect, it lags behind the United States. From 2001 to 2011, transportation in China accounted for 58.4 percent of China's total CO_2 emissions and the total used energy consumption of the country was 1.6% [34]. C. Chen et al. [35] proposed the eco-inefficiency model, which does not require a distinction to be made between poor or potent unwanted performance disposability. The model will increase the desired output while decreasing the unexpected output while keeping the input constant. The research confirmed, in general, that increased economic activity reduces the environmental efficiency of inland transportation. This detrimental effect can be removed but only is mitigated by the introduction of environmentally friendly policies: the advancement of alternative fuels, the generation of electricity from renewable sources, the reduction of noise emissions, the promotion of non-motorised vehicles, and the reduction of the land use of road networks by increased usage of waterways [36]. Due to the impact known as induced travel demand, major investment in road infrastructure projects raises GHG emissions [37]. GHGs have a striking

and inequitable influence on human health since a minority of car owners cause pollution that also affects the less fortunate majority of Chinese society. To break this cycle and shift to less environmentally destructive modes of transportation such as rail, the government needs a smart investment strategy [33]. The research also found that, since 2012, social output has been the least effective part of national inland transport efficiency. While 2011–2015 did do better than 2006–2010 overall for Chinese transportation, not all categories saw improvements. As a percentage of total production, social performance decreased by approximately 15% compared to the 53% and 19% gains in economic and environmental effectiveness, respectively [38]. This diminishing level of social success raises alarm and necessitates immediate action, especially when considered in conjunction with the disturbing profile of victims of traffic accidents [38].

Table 1. Summary of the case studies on sustainable transportation policies by the government for Jordan, Rwanda, and Jamaica.

Item	Jordan	Rwanda	Jamaica
Relationship to sustainability policies with National Strategy for Transport or Growth	A part of the national transportation strategy Course of Action	Part of the Masterplan for Strategic Transport	Part of the National Long-term Growth Strategy
The liable party	Transport Ministry	Development Agency for Transportation	Institute for Country Planning
Highlights of strategy vision	Established and sustainable transport sector achieved	Creation of a transport system supporting sustainable economic activities	No particular reference to the sustainability of transportation
Planning goals highlights	Pursue a multi-modal strategy to protect the environment Decrease adverse repercussion	Establish a framework to guarantee sustainable funding for the maintenance of roads	Achieving a viable framework for road transport that serves the economy and social needs
Inclusion strategies for the role of vehicles highlights	Setting and implementing requirements that strengthen procedures for vehicle inspection Reducing the operating age of cars Regulating pollutant and GHG emissions Improving fuel quality Encouraging renewable fuels	Encouraging the use of the standards of the most environmentally efficient vehicle. The application of new vehicles to public transport	Usage of more energy-efficient modes of transport. Support for vehicles using renewable fuels and technologies
References	[30]	[31]	[32]

Case Studies on India's Situation

Despite having a lower urbanisation rate (32 percent), India's urban population is increasing at a quicker pace than China's since both nations are among the most populous in the world. With 377 million people, India has the second highest urban population in the world [39]. Cities have gained 91 million inhabitants in the last decade (2001–2011), about 56 percent from rural-to-urban migration and net rural–urban classification and the rest 44 percent from natural growth [40]. Forty percent or more of Indian city dwellers take non-motorised modes of transportation, including walking and cycling, on a given day, whereas fifteen percent take public transportation, thirty-six percent take private transportation (twenty percent two-wheeler, sixteen percent four-wheeler), and five percent take intermediate public transit [41]. The forecast also indicates that informal and private–public transportation shares will grow and public transport will decline over the next few decades [41]. The model devised by the author aims to calculate the cost of transportation (public and private) in multivariate regressions but acknowledges the con-

nection between private and public transport [42]. There may be associations between variables that the model fails to account for, including perception and lifestyle as stated in Equation (1) [43].

$$Yij = Xij\ \beta j + Uij \quad (1)$$

With $i = 1, \ldots, N$ and $j = 1, \ldots, m$ representing, respectively, transport and households' expenses (public and private). Here, y_{ij} is a transport expenditure metric, x_{ij} denotes the control variables derived from the survey that corresponds to urban mobility determinants and u_{ij} is the term of error. The jth equation model can be written as Equation (2) after observations are stacked. With the same notations:

$$Yj = Xi\ \beta j + Ui \quad (2)$$

The analysis measures the quantity of transportation by using out-of-pocket travel expenses in comparison to traditional indicators of travel behaviour research, such as time travelled or distance [43]. All money spent in the last month on gas, diesel, lubricants, and other automotive fuels is counted into the total for private car expenses. As opposed to private vehicles, public transportation costs include everything from bus and train fares to taxi fares to steamer or boat fares to rickshaw and horse cart fares to porter and porter charges for the past 30 days to school van and bus fees. Considering the differences in the cost of fuel across cities and the features of the vehicle, the amount spent on out-of-pocket travel may not reflect actual travel by private or public methods of transport. The ability to draw reasonable inferences, including those related to sustainability, is not hindered by this assumption (i.e., the reduction of the use of gasoline) [44]. The results indicated that private transportation's share is greater in smaller communities and lower in larger ones when compared to the use of public transportation. The proxy for the amount of transportation, which can be either the distance travelled or the number of trips taken, population density has a large impact on travel costs for both public and private modes of transportation. With all else being equal, a 10% increase in population density is linked with a 1–1.2% point drop in the share of travel made by private automobiles. This suggests that a doubling of density can result in a 10–12% reduction in transportation needs [44]. The findings will contribute to the design of enhanced transportation and urban networks in the region. Cities in developing nations, such as India, and in highly urbanised and high-income nations, avoid a number of wasteful transit routes. Similar to the earlier study, after correcting for other variables, socio-cultural and socio-economic characteristics rather than city-related variables define the quantity of transit and modal option. Greater assistance for such sustainable mobility strategies in small and medium-sized cities could result in enormous long-term advantages. Compared to larger cities, public transport infrastructure in small towns is often economically unreliable [45]. Densification also appears to be a viable choice for lowering transport volumes and encouraging sustainable modes of transport in Indian urban areas, as has been argued for towns in wealthier countries [46]. A mix of push and pull measures should be implemented to move the growing number of high-income commuters to more sustainable alternatives [44].

3. Road Networking

The road network facilitates trade by providing the arterial network, economic progress, social integration, and transport. It is utilised for the efficient transmission of goods and people. Road traffic has an edge over other modes of transportation due to its door-to-door service, accessibility, operational versatility, and dependability. Consequently, passenger and freight movements in India have increasingly favoured highways over other modes of transportation throughout time [47]. In 2018, 55% of the world's population resided in urban areas as opposed to rural areas. In 1950, 30% of the world's population resided in urban areas; by 2050, it is projected that 68% of the global population will reside in urban areas. Europe (74%), the Caribbean (81%), Latin America, Northern America (with 82% of its population living in urban areas as of 2018) and Oceania (68%) are among the

most urbanised countries [48]. The current rate of urbanisation in Asia is approximately fifty percent. Comparatively, only 43 percent of Africa's population currently resides in metropolitan areas. The world's rural population has continuously increased since 1950 and is predicted to reach its peak within a few years. The global rural population is now close to 3.4 billion and is estimated to increase marginally and then decrease to around 3.1 billion in 2050. Almost 90% of the world's rural population lives in Asia and Africa. India (893 million) has the highest rural population, followed by China (578 million) [48]. Only three countries, Nigeria, China, and India are expected to account for 35 percent of the global urban population growth between 2018 and 2050. India is predicted to add 416 million urban residents, Nigeria 189 million, and China 255 million [48]. Since India has the highest rural population globally, road construction for the same has been of utmost importance, as shown in Figure 3 below [49].

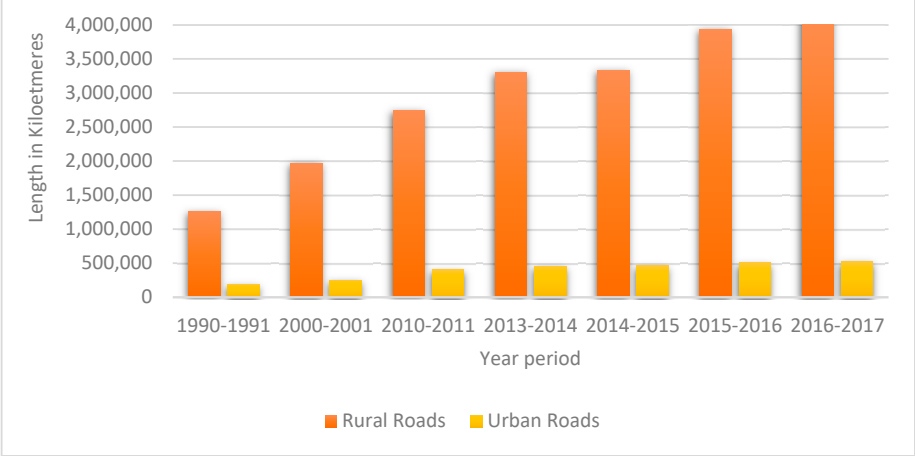

Figure 3. Road construction for rural and urban India in kilometres from 1990 to 2017 [49].

As of 31 March 2017, rural roads comprised the greatest allocation of the road network (70.65 percent) [49]. District roads accounted for the second highest percentage (9.94) which previously Public Health Works (PWD) roads had in the year 2015 [49,50]. The proportion of the total length of the road network of NHs declined from 4.95 percent of the country's total road length prior to 31 March 1951 to 1.79 percent of the country's total road length as of 31 March 2015 and further increased to 1.94 percent in the year 2017 [51]. The share of urban roads increased inconsistently from March 2015 to March 2017 where it was at 8.93 percent from the 8.54 percent recorded in 2015 [49]. The length of state highways has been consistently decreasing from the year 1970–1971 (6.20 percent) to 2016–2017 (2.97 percent) [49–51]. As of 31 March 1971, the share of project roads decreased from 14.31 percent to 5.5 percent as of 31 March 2015 [51]. This increased to 5.58 in the year 2017. Road length in percentage for the year 2016–2017 is shown in Figure 4 [49].

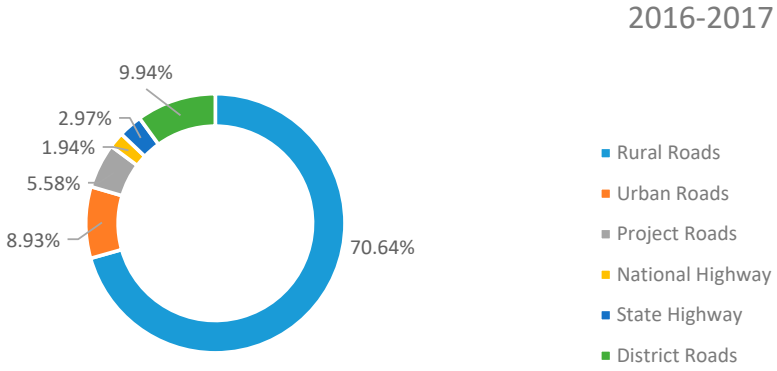

Figure 4. Road length in percentage of different types of roads in India for the period 2016–2017 [49].

3.1. Challenges of Indian Urban Roads

According to several projections, India's urban population will be among the top three in the world; therefore, it is crucial to construct the road network in a sustainable manner. Urban roads include municipal roads under the jurisdiction of the State and Urban Territories (UT) Departments of Urban Development, Railway Zone Roads, Military Engineering Services (MES) MES Roads, and Major and Minor Port Roads. The overall length of urban roadways increased from 467,106 km to 509,730 km from 31st March 2015 to 31st March 2016. The proportion of urban roads within the category of roadways increased from 8.54 percent in 2014–2015 to 9.09 percent in 2015–2016 and further to 8.93 percent in 2016–2017 [49,50]. This percentage is barely sufficient for the growing population of urban India. Few challenges in road policies were identified by Manisha et al. [52].

Despite continual efforts to integrate transportation with land use and regional planning to enable sustainable growth, primarily urban development has been impacted by transportation and national policies have not fully addressed this issue. There are two challenges: initially, there are few national initiatives (e.g., Taskforce on Integrated Transport Policy) [53]. The Integrated National Transport Policy (INTP) of India seeks to combine several forms of "an effective, sustainable, secure, and regionally balanced transport system," but does not address the issues of lowering commute distances and reliance on private modes of transportation [54].

Second, the current proposals concentrate on metropolitan areas (e.g., National Urban Transport Policy 2006 [55] and 2014 [56]). Longer travel distances have rendered non-motorised alternatives impractical, according to the National Urban Transport Policy of 2006 and 2014, which underlines the problem of long travel and the rising use of private vehicles, among other issues. The national transportation policy contains a section on urban transit, whereas rural areas are discussed in less detail [57]. In a similar fashion, the plans for the Metropolitan Region of Mumbai and the National Capital Region of Delhi do not emphasise the rural transport infrastructure, particularly in terms of making the rural hinterland accessible to enterprises for economic development. The ownership of private automobiles, particularly cars and two-wheelers, has expanded dramatically in the Delhi region, and the resulting increase in traffic has prompted environmental concerns [58]. As a result, for the first time, the newly updated Delhi Regional Plan, 2021 National Capital Region implements policies encouraging short trips and switching people from private transport to public transport to minimise pollution [59].

Several major Indian cities have been ravaged by a succession of disastrous urban floods. In 2005, the consecutive flash floods in Mumbai (July), Chennai (October and December), and Bangalore (October) caused considerable economic damage, loss of life, and transportation disruption [60]. In August 2017 in Mumbai and September 2017 in Bangalore, excessive rainfall precipitated catastrophic flooding. As they become the preferred path for stormwater, the transportation infrastructure is immediately affected by flooding. Due to rainfall flooding low-lying urban settlements and burying highways, inadequate and poorly maintained drainage systems are unable to absorb the excessive runoff [61]. The effect of flooding on traffic congestion is a complex phenomenon and, particularly in Indian cities, has not been studied in depth. Urban flooding and associated damage should be seen as a major problem to be tackled, especially for India's megacities. Based on the smart city model, more new and existing cities are expected to be built.

3.2. Challenges of Indian Rural Roads

Access to markets and public services is hampered for many people in developing nations, particularly rural regions of India, because of inadequate transit infrastructure [62]. Rural roads consist of Panchayati Raj roads (Zilla Parishad, Panchayat Samiti, Gram Panchayat), Pradhan Mantri Gram Sadak Yojana roads (PMGSY), and State PWD roads [50]. Shilpa Aggarwal et al. [63] conducted a natural experiment that resulted in a plausibly exogenous difference in the timing and location of paved roads in the Indian village. The major findings underlined the issues generated by inadequate and unpaved roads in rural

India. Despite the fact that market-to-market price convergence is a major indicator of market integration, it only presents itself in traded products. However, the composition of the products exchanged is inherent to the existence of a route, and so the quantity of locally available goods is merely an alternative measure of integration with foreign markets [64]. There is a good justification that producers and investors should also show their support for increasing product accessibility and affordability rather than just listening to consumers' demands in this area. When looking at the factors that influence farmers' choices regarding the introduction of new technologies, it was discovered that those who live in areas with recently built highways were more likely to increase their use of chemical fertiliser and hybrid seeds [65]. Farmers with high gross returns on inputs such as hybrid seeds may still prefer not to implement them if, due to weak infrastructure, there are high costs to procure them. As far as human capital is concerned, the effect on the enrolment of 5- to 14-year-olds at school is positive and negative for 14- to 20-year-olds. The positive results could theoretically result from increased school access. Indeed, there is rich literature in development that finds significant positive impacts of a school building on the enrolment and attendance of children in school [66,67]. By reducing the effective distance (in terms of travel time) and the cost of travelling to school, constructing a road may have similar favourable impacts to those seen in this research, depending on how much closer the operational channel is to the school. The discontinuous leap in the distribution of the likelihood of road construction in the PMGSY scheme is evident: as defined by the program, smaller villages dominated larger villages in terms of construction priority. The priority is not entirely clear, however, as smaller villages tend to get roads before the larger ones are completely completed.

As of 31 March 2016, the total length of rural roads was 3,935,337 km, representing the largest share of the total road network. Out of 3,935,337 km of rural roads, the States/UT Departments of Panchayati Raj reported 1,860,573 km of Panchyati Raj Roads; 626,377.42 km of PMGSY Roads were reported by the National Rural Road Development Agency (NRRDA) of the Ministry of Rural Development [67,68]. Rural Development; under the former Jawahar Rozgar Yojana (JRY) in service from 1990–1999, 548,387.01 km by state PWDs and the remaining 9 lakhs km (nine lakh km) of roads were built [50]. This data seems promising, yet the number of access paths is insufficient for the world's highest rural population.

4. Traffic Density for India and Behavioural Analysis of Drivers

For the second consecutive year, Mumbai has been ranked as one of the most traffic-congested cities in the world as per the (global positioning system) GPS-based report on traffic congestion as given in Table 2 [69]. TomTom, an Amsterdam-based company that provides traffic solutions, published the 2018 Traffic Index by using position technology to gather traffic data. This index ranks 403 cities, including 13 new cities, across 56 countries for the year 2018. Bogota in Colombia and Lima in Peru were second and third, respectively, on the list, while Moscow, the Russian capital, was fifth. Delhi is the fourth city in the world with the most traffic congestion. Congestion was expressed in terms of the time it took to go somewhere, as opposed to when the road would have been less crowded. When traffic is bad in Mumbai, it can add an extra 65% to the time it takes to go somewhere, while in Delhi, it can add an extra 58% [70]. According to the report, between 2017 and 2018, approximately 75 percent of the total cities accounted for in the 2018 index, had increased or stable congestion levels, with only 90 cities showing measurable declines [68,69].

Table 2. Traffic congestion level of the top 10 cities all around the world [70–73].

Rank	City	Country	Congestion Level	Rank	City	Country	Congestion Level
01	Mumbai	India	65%	01	Bengaluru	India	71%
02	Bogota	Colombia	63%	02	Manila	Philippines	71%
03	Lima	Peru	58%	03	Bogota	Colombia	68%
04	New Delhi	India	58%	04	Mumbai	India	65%
05	Moscow region (oblast)	Russia	56%	05	Pune	India	59%
06	Istanbul	Turkey	53%	06	Moscow region (oblast)	Russia	59%
07	Jakarta	Indonesia	53%	07	Lima	Peru	57%
08	Bangkok	Thailand	53%	08	New Delhi	India	56%
09	Mexico City	Mexico	52%	09	Istanbul	Turkey	55%
10	Recife	Brazil	49%	10	Jakarta	Indonesia	53%

With four of its cities among the ten most congested cities globally, India has topped the 2019 traffic index. Bengaluru (71%), Mumbai (65%), and Pune (59%) were ranked first, fourth, and fifth, respectively. Manila from the Philippines, Bogota from Colombia, Moscow from Russia, Lima from Peru, Istanbul from Turkey, and Jakarta from Indonesia are some of the other global cities in the top 10. The study results, a report detailing the traffic situation in 416 cities in 57 countries, have been published by the use of location technology for the year 2019. With a 56 percent congestion level (extra travel time stuck in traffic), New Delhi takes the eighth spot this year. On average, Delhi drivers spend an additional 190 h during peak hours, i.e., 7 days, 22 h per year in traffic [71,72]. The city's congestion peaked on 23 October 2019, at 81%, and it dipped to 6% on 21 March 2019, at its lowest point. When comparing the 2018 and 2019 traffic indices, we see that congestion in Delhi has decreased by 2%. People in Bengal who have to commute during rush hour spend an extra 243 h, or 10 days and 3 h, in traffic each year. During rush hour, Mumbai drivers spend an additional 209 h on the road, or 8 days and 17 h every year stuck in traffic. Those who must travel in Pune during rush hour spend an extra 193 h, or 8 days and 1 h every year, stuck in traffic. Global traffic congestion has worsened over the past decade, with 239 of the 350 cities in the latest Traffic Index research experiencing worsening conditions between 2018 and 2019, while only 63 saw improvements. Despite being an indicator of a healthy economy, the worldwide increase in congestion often costs economies billions [70,71]. Indian cities have reduced pollution as per the reports of 2021 with Mumbai being ranked 5th, Bengaluru being in the 10th rank and New Delhi in the 11th [73].

Mixed traffic circumstances, characterised by a wide variety of vehicle types, are common in countries with emerging economies such as India, China, Bangladesh, etc. Different vehicle kinds, each with its own unique set of dynamic and static characteristics, lead to driving styles that are specific to each vehicle's class [20]. C. R. Munigety et al. [20] first establishes the impact of the type of vehicle on the longitudinal and lateral movement behaviours of drivers using the trajectory data collected in India and then introduces, based on the same dataset, the proposed dependent driver behavioural vehicle type models. Using a simulation setting that accounts for vehicle movements that do not adhere to lanes, the proposed models' efficiency is then tested against real-world data to ensure accuracy. Data analysis revealed many interesting facts about the drivers and vehicles, including their average speeds, acceleration ranges, vehicle sizes, and the overall make-up of the surrounding traffic. Drivers of various vehicles were seen to travel at speeds ranging from 14 metres per second (m/s) to 9 m/s (m/s), which reflects the varying degrees of manoeuvrability amongst vehicles. It was also observed that there was a sizable gap between the fastest and slowest vehicles on the road due to the vast disparity in vehicle

size. In order to learn how drivers follow the example of others, researchers gathered data on the space headways held by different leader–follower vehicle style combinations. A total of 179 datasets were selected for the analysis. Statistics including mean and standard deviation for various pairs of lead and trailing vehicle speeds and following distances are included in these datasets' descriptive statistics. However, the typical distance between vehicles in pursuit varies depending on the mix of vehicles used. When a motorcycle was either the lead or the trailing vehicle, the average following headway was lower than it would have been for a larger vehicle. Motorcycles' smaller size and increased agility may be to blame. These actions may indicate the vehicle is engaging in the following behaviour, albeit the specifics of that behaviour will vary depending on the combination of vehicles being considered [20]. The research was also conducted to get insight into lateral movement driving activities by analysing the lengths and numbers of lateral movements generated by each vehicle type. Amount of time needed for a 2 m lane change in each vehicle type. The shortest of these is 4 s (typical of motorcycles), while the longest is 9 s (for auto-rickshaws). This may be due to the fact that vehicles of varying sorts have varying degrees of lateral manoeuvrability. The trajectories were then analysed in accordance with the generally accepted notion of lateral movement in order to identify all the lateral motions that occurred for each vehicle class (lateral shift equal to 3.5 m). It was found that motorcyclists and drivers of other small cars rarely made lateral manoeuvres. However, a visual examination revealed that drivers of compact cars often made lateral movements inside and across lanes [20].

Caitlin N. Popes et al. [74] in the United States of America, studied the relationship between age, executive function behavioural manifestations, and self-reported distracted driving behaviours. An increased risk of motor vehicle collisions (MVCs) is associated with performing secondary activities, such as texting while driving. While cognitive processes are involved in driving, such as executive function, little is known about the relationship between executive control and willingness to participate in distracted driving. Participants were predominantly Caucasians (59.3 percent) and African Americans (32.2 percent) and women (59.3 percent) in the total study. Post hoc studies found that young and middle-aged adults were more distracted than older adults while driving [74]. There was no substantial difference between genders when measuring driving experience, calculated as months from full licensing [74]. Compared to middle-aged drivers (307.95 months) and older drivers, who both had more experience than younger drivers (34.08 months), a post hoc test found that older drivers had the most driving experience (649.96 months) [74].

Sheila G. Klauer et al. [75] also researched distracted driving attributes to the performance of secondary tasks being the primary cause of motor vehicle collisions (MVCs) in the United Kingdom. While dialling a mobile phone, inexperienced drivers ($Mean_{age}$ = 16.4) were eight times more likely to have an MVC or near-crash, while seasoned drivers were more than two times more likely [75]. Among middle-adults and adults, the author reported distracted driving activity [76]. It was found that 66% of 715 persons aged 30–64 were texting when stopped at red lights. This number represents 56% of all driving time spent on mobile devices. Specifically, older age predicted less engagement in distracted driving behaviours, making age a major predictor of this dangerous trend [76].

Yanning Zhao et al. [77] in Aichi Prefecture, Japan, conducted a two-month experiment of 108 participants. Data from probing vehicles (PVs) rather than surveys or simulators were used to learn about the ways in which the elderly commute. Since a sizable amount of PV data may be collected during an extended on-road trial, bias from survey testing and simulation errors can be sidestepped. This study analyses several aspects of driving behaviour, such as route preference, left/right turn frequency, and average speed. Before the tests were conducted, a questionnaire was used to gather information about the driver. People were asked 18 questions that were directly related to the topic. Age (mean = 40.3, standard deviation = 11), gender, and employment status are used to categorise the experiment participants; those participants who are older drivers (10 samples, 9.3 percent)

and those who are not employed (11 samples, 10.2 percent) make up a relatively small percentage of the total [77].

It was found from the research that older drivers (60 years of age or older) had the lowest rate of travel during peak hours (7:00–10:00 and 15:00–20:00) and showed the highest rate at the age of 50. It is reasonably straightforward to understand the former since most older drivers did not have to ride during peak hours after they retired. The latter phenomenon may be based on the belief that younger people (20s, 30s, and 40s) were driving not just for travel but also for other purposes such as shopping and leisure activities, but 50s were inclined to use vehicles as a travel tool and at other times preferred other methods of transport [77]. At first glance, this study's findings are unsurprising: senior drivers are less confident on expressways than their younger counterparts. This tendency continues even over very long trips. Studies based on questionnaires have found that elderly drivers are more likely to take a longer route or drive straight through an intersection rather than make a right turn from the left lane for safety reasons (turning left while driving on the right). There are a number of plausible causes, but one is that drivers are increasingly relying on their GPS systems to help them decide whether or not to enter junctions. Results indicate that more intersection aids should be constructed and installed to improve the safety of senior drivers at intersections when cars and other vehicles are present [77].

5. Difference in Green Rating Systems for Roads

Over the past decade, many different urban sustainability certification (USC) systems have been introduced, most of which are updates to existing building sustainability certification schemes. The United States Leadership in Energy and Environmental Design (LEED-ND), the United Kingdom's Building Research Establishment Environmental Assessment Methodology (BREEAM), Abu Dhabi's Pearl Community Rating System (PCRS), Australia's Green Star Groups, Germany's Certification from the Sustainable Building Council (DGNB) for urban districts, Qatar's Global Sustainability Assessment Scheme (GSAS), India's Green Townships under the Indian Green Building Rating System (IGBC), and the United Arab Emirates Global Sustainability Assessment Scheme (GSAS) are all examples of USC's [78]. The author, therefore, focuses on only one urban sustainability theme, namely sustainable transport, within four separate USCs, and assesses the relevance of their prescribed steps to the prevailing conditions of transport, in particular in developing countries [78]. The approach is primarily based on the study of the material of the current versions of four USC systems, namely LEED-ND V4 [79], BREEAM-C [80], CASBEE-UD [81], and PCRS V1 [82]. The four USCs were chosen since it represents not only different nations but also various zones: East Asia, the Middle East, Europe, and North America. Furthermore, these rating systems are free to use and accessible in English.

Although several standards and themes within USCs may seem unrealistic in terms of what can be accomplished on the neighbourhood or community scale physically (e.g., lowering indoor and outdoor water consumption and conserving energy through district heating and cooling and improving the urban environment). Structured planning and the existence of such needs are prerequisites for implementing sustainable transportation. Knowing what USCs mean by "neighbourhoods and communities" and how they conform to sustainable transport plans is therefore essential [78]. The promotion of eco-friendly modes and mutual trips, the prevention of polluting modes, the enhancement of the public realm, the mitigation of the effects of heat islands, and the encouragement of compact production of mixed-use all fall under the umbrella of "sustainable transport," a key component of urban sustainability. The objective or function of several provisions in all USCs is devoted to advancing sustainable transportation.

A lengthy duplication of the USC manuals is necessary to illustrate how each criterion relates to sustainable transport, as it lists the objectives and measures of the 55 specified criteria. Moreover, it is evident from the titles (e.g., walking streets, transport evaluation, and traffic safety) that the majority of requirements are related to transportation. To avoid

subjectivity, a concise description must be provided for the rare criteria where such a link is uncertain. The "Smart Location" and "Agricultural Land Conservation" requirements within LEED-ND encourage developers to locate sustainable build sites by various options, including a site served by a good transit system [83]. "Green Infrastructure" in BREEAM-C calls for green spaces to be situated within a walkable distance from all residents, which facilitates walkability [84]. "Crime Reduction" measures the night lighting of streets, plazas, and parks in CASBEE-UD, which in turn has a direct effect on active transport and public transport. Convenience "and" Health and Safety, Education "measure the distance of various land uses (e.g., supermarkets, schools, hospitals) from block entries" [85]. Ground Greeninganalyses the given green spaces and their effects on the heat island effect mitigation. Finally, Modular Pavement and Hardscape Cover in PCRS calls for the use of modular materials that mitigate the impact of heat islands in the public and right-of-way sphere [86]. All four USCs provide multiple requirements aimed at promoting active transportation directly and indirectly. They reflect 17 of the LEED-ND criteria, 11 of the BREEAM-C criteria, 13 of the PCRS criteria, and seven of the 29 QUD criteria of the CASBEE-UD section, as shown in Figure 5 [78].

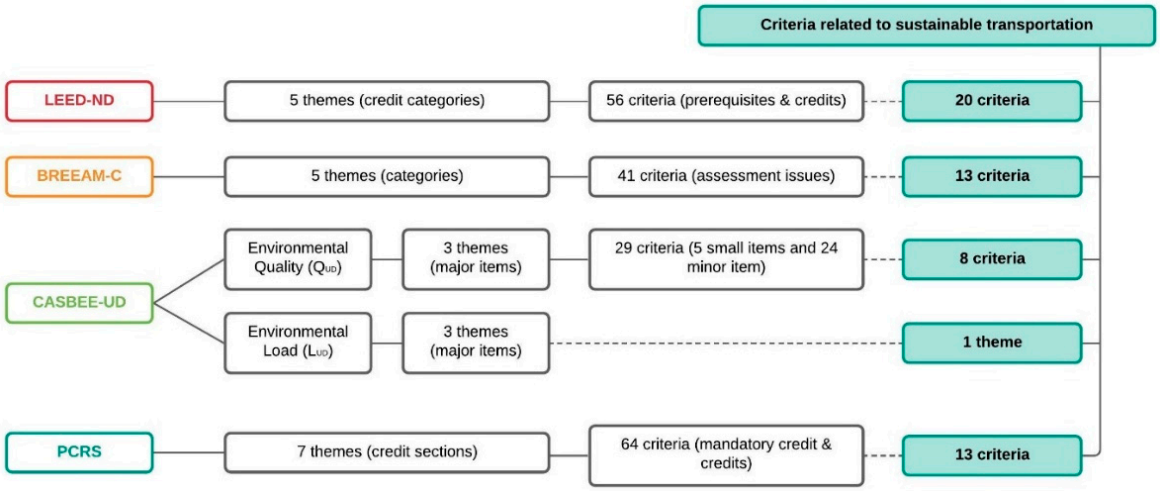

Figure 5. Promotion of active transportation by the four USCs showing the number of criteria required in each of them [78].

Active transportation and public transit are the only two important parts of sustainable transportation that are often targeted by standards and carry a lot of weight. Active transportation includes things such as walking and biking, which are self-propelled and powered by people. Since it sounds better than "sluggish," the word is used more often. Increased use of energetic transportation offers several advantages for both society and people such as better mobility, more safety, better fitness and public health, more community cohesion, less traffic congestion, less pollution, less expensive motorised infrastructure, open space preservation, and higher property value [87]. Multiple lighting considerations, a clear spacing at crossings, integrated design indicators, signs and shared areas, and a minimal sidewalk area, among others, are safeguarded by requirements that are both safe and practical. In addition, cycling paths must be straight, secure, and connected to existing routes from neighbouring communities, with a nominal thickness of 2 m or 1.5 m on roads with traffic speeds of 64 km/h or less [88]. PCRS needs a 25% reduction in walking distances for all relevant services (i.e., a walking distance of 525 m instead of 700 m to neighbourhood centres that include community centres, hospitals, early learning centres/nurseries, and community police points) relative to local standards in Abu Dhabi. It also includes pedestrian route connectivity with a direct route index of less than 1.5 [89]. CASBEE-UD reports that for "Level 3" less than 600 m and less than 300 m for "Level 5," the distance to daily facilities, medical/welfare facilities, and educational facilities from the farthest point in an area covering 80 percent or more of both the working population and

the resident population in a block to the facilities should be less than 800 m. CASBEE-UD also supports the creation of "comprehensive transport initiatives" that facilitate a balance between different types of transport, including bicycles [81]. "Public transport is a crucial necessity for the sustainable city of the 21st century" and supports active transport as users of public transport are more likely to cycle and non-transit users for longer distances. As a result, USCs provide different requirements and follow various methodologies to enable people to use public transport and enhance facilities and services. In general, eleven, eight, and three requirements were found to be linked to public transport in the LEED-ND, BREEAM-C, and PCRS, either in terms of goals or in terms of steps. In CASBEE-UD, there are three linked requirements in the QUD and one theme in the LUD. The public transport facilities listed in USCs, however, have several characteristics and characteristics that are not accessible in many cities and even nations because these characteristics and standards vary greatly in different contexts [90]. The author found after comparing the four USCs in terms of sustainable transport, while the USCs recommend several steps, it has been found that only active and public transport has several allocated requirements and substantial weight, which, if ignored, may hamper the achievement of some certifications or high benchmarks. As for involved residents, transportation was analysed in order to compare the walking and cycling distances indicated in the USCs and the typical journey duration for walking and cycling in various nations to the average size of certified developments. The results indicate that the provision of safe and easy walking and cycling environments exclusively within these projects would deliver negligible benefits due to the relatively small site area of the certified developments if these environments are disrupted beyond their limits [78].

Based on the outcomes of the comparison analysis, the credit structuring of the two Indian schemes, the Green Rating for Integrated Habitat Assessment (GRIHA) and the IGBC technique, were appraised. Although these two schemes are designed for the same context and use the same codes, there are only a few similarities between them, and there are numerous differences in terms of credit structuring, the number of evaluation indicators used, and the distribution of scores across different categories and indicators [91]. It is noted that the "category group" layer is not implemented in these schemes. As a result, there is no clear indication of whether their evolution is carried out based on sustainable development's triple-bottom-line characteristics (TBL). The TBL is an accounting system that combines three performance dimensions: social, environmental, and financial. The TBL captures the essence of sustainability by assessing the effect of the actions of an organisation in the world [91]. In both systems (GRIHA: 20 percent; IGBC system: 28 percent), the relative significance assigned to the "power" group is highest. More points in GRIHA (13 percent) are allocated to the "energy efficiency" indicator within the energy group [92]. Similarly, in the IGBC framework (15 percent), the "enhanced energy efficiency" indicator has more marks [93]. The relative importance of primary green building scheme groups where energy element is given the greatest weight among the main categories. In addition to the indicators under the energy category, an energy-related indicator such as "passive architecture" is included in the IGBC framework under another category called "sustainable architecture and design." The lowest weight in GRIHA is given to the main category "waste and contamination component." In the IGBC framework, two main groups, "waste and emissions" and "management aspects" are assigned the lowest weight of 7 percent [93]. Triple-bottom-line analysis revealed that both the IGBC system and GRIHA are environmentally focused schemes with economic considerations playing a secondary role. GRIHA assigns relative weights of 70%, 4%, and 20% to the environmental, economic, and sociocultural factors, respectively, and 6% to the procedural factors [92]. The IGBC technique gives environmental, economic, and sociocultural factors respective weights of 68.3 percent, 7.2 percent, and 16.5 percent. In the IGBC system, procedural considerations carry an 8 percent weight. The IGBC scheme consists of a few mandatory eligibility requirements for each category. Such conditions are desirable for retaining a threshold in each category. To lessen the relative significance of primary categories in green building plans, the IGBC

indicator "passive architecture" must be adopted in places with a moderate environment. IGBC's site selection and planning category prioritise closeness to public transportation and low-emitting automobiles, which is the most sustainable form of transportation. It is observed that Indian systems are not adapted to fit the diverse regional characteristics and meteorological circumstances in India. The National Building Code of India defines the hot–dry (Gujarat and Rajasthan), hot–humid (coastal regions), temperate (hill stations), cold (Kashmir), and composite (Delhi, Uttar Pradesh, and Madhya Pradesh) climate zones of the Indian subcontinent [94].

6. Challenges and Solutions for Sustainable Transportation

The influence of flooding on traffic congestion is a complex issue that has not been thoroughly explored, particularly in Indian towns. Urban flooding and the resulting damage should be seen as a significant issue, especially for India's megacities. On the basis of the smart city paradigm, it is anticipated that more new and existing cities would be constructed [95]. A smart city in India will be understood differently than in, say, Europe. Even in India, there is no way to define a smart city. To organise cities inside the mission, some definable boundaries are required. In the imagination of every city dweller in India, a smart city includes a wish list of services and amenities that reflects his or her level of ambition. The ideal goal of urban planners is to construct the entire urban ecosystem, as described by the four pillars of comprehensive growth—structural, physical, social, and economic infrastructure—in order to suit the requirements and wishes of the population. This can be a long-term objective and cities can work incrementally to build such comprehensive infrastructure, adding layers of "knowledge" [96]. To lessen the uncertainties associated with primary data collection based on studies and observations at the time of the flood, experimental flood data on the safe speed and collection of information regarding transportation operations during the flood situation are necessary. Work in material science and long-lasting roads will be advantageous [95]. Governments favoured urban road networks in the second half of the 20th century and refused to give major public funds to urban rail projects. Back on the urban development agenda is urban rail. It thrives in highly crowded cities in Asia, Europe, and the Middle East, as well as in places that rely largely on cars, such as the United States of America and Australia. China and India have launched over 25 high-capacity urban rail lines (metro rail) over the past two decades, with another 25 under construction. Increasing inequalities in journey time between urban rail and urban traffic, as well as the rising demand for urban rail-facilitated dense urban centres, are largely responsible for this expansion. Support, however, is a continuing struggle with the traditional model of government grants and fare-box revenue, which is insufficient to meet the rising demand for rail transportation [97]. It is essential to focus on railways as they can remove the traffic congestion on roads, prevent accidents, provide safer means for women travellers, cheaper than public land road services, destinations are reached quicker than road transports, and are highly environmentally friendly.

Urbanisation, on the other hand, would broaden the range of economic opportunities available to India's underprivileged populations, particularly women, by creating a wider range of occupations. This allows a large number of women to work in the rapidly developing and more feminised service and industrial industries. On a global scale, gender studies on gender dimensions of transportation are expanding. It emphasises the fact that women's transportation habits continue to contrast with men's due to income gaps, established gender stereotypes, cultural norms regarding appropriate transit conduct, and safety concerns. The study of commuting patterns segregated by gender and form of the region (rural or urban) is thus a crucial prerequisite for the implementation of social justice and gender equality policies [98]. According to the findings, rural areas have a more sustainable transportation behaviour than metropolitan ones. Financial growth and an increase in personal vehicle ownership, however, can easily alter this situation, contributing to the prevalence of environmentally unsustainable patterns of mobility [52]. If sustainable transportation is to be achieved in both rural and urban India,

it is necessary to create policies with this consideration in mind. By focusing more on safer and quicker modes of public transportation, it is possible to prevent the rise of four-wheeler supremacy in large cities, two-wheeler dominance in small cities, as well as the ownership of automobiles. These vehicles can be electric vehicles (EVs) which are the next generation of sustainable transportation modes [52,99]. The low provision of rail services in the country, compared to highways, which are more pronounced in rural areas, appears to be one issue. Two important criteria for mitigating the environmental effect of road transport in India have been established since the early 1980s: (i) to minimise vehicle personalisation and (ii) to boost the emission profile of existing vehicles by using cleaner fuel such as hydrogen, etc. [100]. Delhi metro increased opportunities for equity and ridership among various sections of society in terms of socioeconomic impacts, while an estimated positive environmental effect near one of Delhi's major traffic intersections (in 2004–2006) with a 34 percent reduction in carbon monoxide emissions [100]. Plastic waste will be used by the government for road building. One of the plastic waste roads was recently developed near Dhaula Kuan (New Delhi) with plans to construct the Delhi-Meerut Expressway and the Gurugram-Sohna road [101]. So, the government is also seen taking certain steps to assure sustainability in transport systems, and yet a lot of other methods need to be applied. Furthermore, in these congested metropolitan areas, the alignment of non-motorised and other fast transit lines, as well as the paratransit system, is badly needed to transfer a major number of personal transport modes to sustainable transportation options [101].

7. Conclusions

The paper discusses various areas in the transportation sector of India where attention is essential. Apart from changing the vehicle engine and switching to cleaner fuel, various other areas are also needed to be taken care of to attain sustainability. In the first section, there is a comparison between three developing countries on the policy changes that have been completed by their respective governments to attain sustainability in transportation.

- A case study on China showed an assessment against the 11th- and 12th-year plans and highlighted the important points of the policy changes.
- A travel expense case study was studied for the Indian road system and public transport is better than private means was concluded, although the reach of public transport in rural India is scarce, which should be managed. Various challenges regarding the urban and rural road systems of India were considered and it showed that while urban road systems needed better drainage and long-lasting construction materials, rural roads lacked in providing enough accessibility. The need for women's safety during transit and the lack of which was unable to provide them with career opportunities has also been discussed, and our policies should be planned around it.
- Next, the traffic density and driver behaviour were studied, upon which the matters regarding road safety and environmental protection were brought to the limelight. Traffic density data will help in better understanding of road design to have smoother travel for the drivers. The conclusions on behaviour showed how technology is affecting drivers of various age groups these days, why it is happening and how the road design can be changed to accommodate those changes and provide a better, sustainable road design. Certain limitations were seen with not having enough data on older women drivers, not having a bigger sample size and no psychological data on the behaviour.
- Further studies are essential to counter these shortcomings. Six urban sustainability certification systems were compared with two belonging to India. It was found that although India paid equal attention to energy and the environment, it still lacked in providing specific solutions based on climatic zones and on sustainable transportation, which was better than the other USCs. Extensive studies are essential for studies on Indian systems in these areas.

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References

1. Sustainable Development Goals | UN-Habitat. Available online: https://unhabitat.org/about-us/sustainable-development-goals (accessed on 26 September 2020).
2. Sustainability | Academic Impact. Available online: https://academicimpact.un.org/content/sustainability (accessed on 30 September 2020).
3. Sustainable Development Definition: Historical Background and Examples. Available online: https://youmatter.world/en/definition/definitions-sustainable-development-sustainability/ (accessed on 23 October 2020).
4. Global Warming of 1.5 °C. Available online: https://www.ipcc.ch/sr15/ (accessed on 23 October 2020).
5. United Nations | Peace, Dignity and Equality
 on a Healthy Planet. Available online: https://www.un.org/en/ (accessed on 24 October 2020).
6. World Business Council For Sustainable Development (WBCSD). Available online: https://www.wbcsd.org/ (accessed on 24 October 2020).
7. The Sustainable Development Agenda-United Nations Sustainable Development. Available online: https://www.un.org/sustainabledevelopment/development-agenda/ (accessed on 30 September 2020).
8. Pachauri, R.K.; Reisinger, A. *Climate Change 2007*; IPCC: Geneva, Switzerland, 2007; ISBN 9291691224.
9. Ministry of Environment Forest and Climate Change (MoEF&CC). *India: First Biennial Update Report to the United Nations Framework Convention on Climate Change*; MoEF&CC: New Delhi, India, 2015; ISBN 9111246952.
10. Summary, E. *Stern Review: The Economics of Climate Change*; IPCC: Geneva, Switzerland, 2006.
11. Effects | Facts-Climate Change: Vital Signs of the Planet. Available online: https://climate.nasa.gov/effects/ (accessed on 24 October 2020).
12. Jarraud, M.; Steiner, A. *Summary for Policymakers*; IPCC: Geneva, Switzerland, 2012; Volume 9781107025, ISBN 9781139177245.
13. Aspects, S. WGIIAR5-PartA_FINAL. Available online: https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-PartA_FINAL.pdf (accessed on 23 October 2020).
14. Tracking Transport 2020-Analysis-IEA. Available online: https://www.iea.org/reports/tracking-transport-2020 (accessed on 3 October 2020).
15. Classification of Transportation-CIVIL CREWS. Available online: https://civilcrews.com/?s=classification+of+transportation (accessed on 26 November 2020).
16. *Transportation, An Introduction*; Elsevier: Amsterdam, The Netherlands, 2019; ISBN 9780128134542.
17. Krzywinski, J.; Dresden, T.U.; Engineering, I.D. Design Concept Development in Transportation Design. In Proceedings of the Undisciplined! Design Research Society Conference 2008, Sheffield Hallam University, Sheffield, UK, 16–19 July 2008.
18. Faso, B.; Salvador, E.L.; Georgia, G.; Republic, K.; Islands, M.; Of, S. Supporting Countries in Unprecedented Times. Available online: https://www.oecd.org/coronavirus/policy-responses/developing-countries-and-development-co-operation-what-is-at-stake-50e97915/ (accessed on 30 September 2020).
19. Boubaker, S. ScienceDirect Impact of intersection type and a vehicular fleet's hybridization level on energy consumption and emissions. *J. Traffic Transp. Eng.* **2016**, *3*, 253–261. [CrossRef]
20. Munigety, C.R. ScienceDirect Modelling behavioural interactions of drivers' in mixed traffic conditions. *J. Traffic Transp. Eng.* **2017**, *5*, 284–295. [CrossRef]
21. Kepaptsoglou, K.; Milioti, C.; Spyropoulou, D.; Haider, F.; Karlaftis, A.G. ScienceDirect Comparing traveler preferences for BRT and LRT systems in developing countries: Evidence from. *J. Traffic Transp. Eng.* **2020**, *7*, 384–393. [CrossRef]
22. Davis, S.C.; Boundy, R.G. *Transportation Energy*; Oak Ridge National Laboratory (ORNL): Oak Ridge, TN, USA, 2021; ISBN 1800553684.
23. Ministry of Environment, Forest and Climate Change, Government of India. *India: Second Biennial Update Report to the UNFCCC*; Ministry of Environment, Forest and Climate Change, Government of India: New Delhi, India, 2018; ISBN 9788193853122.
24. Ramani, T.; Zietsman, J.; Eisele, W.; Rosa, D. Developing Sustainable Transportation Performance Measures for TxDOT's Strategic Plan: Technical Report. 2009; p. 7. Available online: https://rosap.ntl.bts.gov/view/dot/16844 (accessed on 23 October 2020).
25. Zhao, X.; Ke, Y.; Zuo, J.; Xiong, W.; Wu, P. Evaluation of sustainable transport research in 2000–2019. *J. Clean. Prod.* **2020**, *256*, 120404. [CrossRef]
26. United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP)-UN India. Available online: https://in.one.un.org/who-we-are/unescap-india/ (accessed on 12 October 2020).
27. Illahi, U.; Shafi Mir, M. Assessment of transport sustainability using a hybrid approach: A comparison of four metropolitan cities of India. *Case Stud. Transp. Policy* **2021**, *9*, 703–714. [CrossRef]
28. Abu-Eisheh, S.; Kuckshinrichs, W.; Dwaikat, A. Strategic Planning for Sustainable Transportation in Developing Countries: The Role of Vehicles. *Transp. Res. Procedia* **2020**, *48*, 3019–3036. [CrossRef]

29. General Framework-Ministry of Transport. Available online: http://www.mot.gov.jo/En/Pages/General_Framework (accessed on 13 October 2020).
30. Planning, T.; Directorate, D.; Studies, T.; Abu, S.; Eng, H.; Eng, A.H.; Ministry, R.A.; Uthayna, U.; Abi, B.; St, W.; et al. Jordan Long Term National Transport Strategy and Action Plan. 2018; pp. 1–77. Available online: https://www.mot.gov.jo/EBV4.0/Root_Storage/EN/EB_Info_Page/long-term_national_transport_strategy_project.pdf (accessed on 30 September 2020).
31. Lombard, P. *Republic of Rwanda Strategic Transport Master Plan for Rwanda*; Aurecon South Africa (Pty) Ltd. Aurecon Centre: Lynnwood Manor, South Africa, 2012. Available online: https://rtda.gov.rw/fileadmin/templates/publications/Updated%20RSTMP%20Final%20Report_combined_2.pdf (accessed on 30 September 2020).
32. Plan, N.D. Vision 2030 National. Available online: https://www.biprogy.com/e/about/management_policy.html (accessed on 12 October 2020).
33. Stefaniec, A.; Hosseini, K.; Xie, J.; Li, Y. Sustainability assessment of inland transportation in China: A triple bottom line-based network DEA approach. *Transp. Res. Part D Transp. Environ.* **2020**, *80*, 102258. [CrossRef]
34. Nations, U.; Commission, E.; Africa, F.O.R.; Nations, U.; Commission, E.; Europe, F.O.R.; Nations, U.; Commission, E.; Latin, F.O.R.; Caribbean, T.H.E.; et al. *United Nations Economic Commission for Africa the Case of Inland Transport Transport for Transport for Sustainable Development the Case of Inland Transport*; United Nations Publications: New York, NY, USA, 2015; ISBN 9789211170962. Available online: https://unece.org/DAM/trans/publications/Transport_for_Sustainable_Development_UNECE_2015.pdf (accessed on 12 October 2020).
35. Chen, C. Measuring Eco-Inefficiency: A New Frontier Approach Measuring Eco-Inefficiency: A New Frontier Approach. *Oper. Res.* **2014**, *60*, 1064–1079. [CrossRef]
36. Zhao, F.; Liu, F.; Liu, Z.; Hao, H. The correlated impacts of fuel consumption improvements and vehicle electri fi cation on vehicle greenhouse gas emissions in China. *J. Clean. Prod.* **2020**, *207*, 702–716. [CrossRef]
37. Özuysal, M.; Tanyel, S. Induced Travel Demand in Developing Countries: Study on State Highways in Turkey. *J. Urban Plan. Dev.* **2008**, *134*, 78–87. [CrossRef]
38. WHO. Global Status Report on Road. Available online: https://www.who.int/publications/i/item/9789241565684 (accessed on 12 October 2020)ISBN 9789241565684.
39. Territories, U. Census of India 2011. 2018. Available online: https://en.wikipedia.org/wiki/2011_Census_of_India (accessed on 30 September 2020).
40. Bhagat, R.B. Emerging Pattern of Urbanisation in India. *Econ. Political Wkly.* **2014**, *46*, 10–12.
41. Planning Commission. *Eleventh Five-Year Plan, Volume III: Agriculture, Rural Development, Industry, Servi ces and Physical Infrastructure*; Oxford University Press: New Delhi, India, 2008.
42. Karathodorou, N.; Graham, D.J.; Noland, R.B. Estimating the effect of urban density on fuel demand. *Energy Econ.* **2010**, *32*, 86–92. [CrossRef]
43. Perkins, T. Travel Behaviour: A Review of Recent Literature. Department of Urban and Regional Planning, Curtin University. Available online: https://tfresource.org/topics/Travel_Behaviour_A_review_of_recent_literature.html (accessed on 12 October 2020).
44. Ahmad, S.; Puppim de Oliveira, J.A. Determinants of urban mobility in India: Lessons for promoting sustainable and inclusive urban transportation in developing countries. *Transp. Policy* **2016**, *50*, 106–114. [CrossRef]
45. Badami, M.G.; Haider, M. An analysis of public bus transit performance in Indian cities. *Transp. Res. Part A Policy Pract.* **2007**, *41*, 961–981. [CrossRef]
46. Compact City Policies | READ Online. Available online: https://read.oecd-ilibrary.org/urban-rural-and-regional-development/compact-city-policies_9789264167865-en#page28 (accessed on 16 October 2020).
47. RI, K. No TitleΕΛΕΝΗ. *UU Kesehat*. 2009, pp. 298–304. Available online: https://morth.nic.in/road-transport (accessed on 12 October 2020).
48. World Urbanization Prospects: The 2018 Revision. Population Division of the United Nations Department of Economic and Social Affairs (UN DESA). 2018. Available online: https://esa.un.org/unpd/wup/ (accessed on 12 October 2020).
49. Ministry of Road Transport and Highways Transport Research Wing "Basic Road Statistics of India" [2016–2017]. 2019, p. 83. Available online: https://morth.nic.in/sites/default/files/Basic%20_Road_Statics_of_India.pdf (accessed on 12 October 2020).
50. MInistry of Road Transport and Highways. Basic road statistics of india 2015–2016. *Transp. Highw. Transp. Res. Wing New Delhi* **2015**, 1–68. Available online: https://morth.nic.in/sites/default/files/File3100.pdf (accessed on 12 October 2020).
51. MoRTH Basic Road Statistics of India 2012–2013. *Minist. Road Transp. Highw. Gov. India* **2013**, *13*, 70.
52. Jain, M.; Korzhenevych, A.; Hecht, R. Determinants of commuting patterns in a rural-urban megaregion of India. *Transp. Policy* **2021**, *68*, 98–106. [CrossRef]
53. Verma, A.; Velmurugan, S.; Singh, S.; Gurtoo, A.; Ramanayya, T. V ScienceDirect ScienceDirect Indian auto-mobility 2020: A Perceptive picture. *Transp. Res. Procedia* **2020**, *25*, 4932–4945. [CrossRef]
54. Capacity, U.; Workshop, B. *Integrated National Transport Planning and Policy Formulation*; School of Planning and Architecture: New Delhi, India, 2015; Available online: https://www.unescap.org/sites/default/files/07%20Integrated%20transport%20planning%20and%20Policy%20Formulation.pdf (accessed on 12 October 2020).
55. Urban, N.; Mission, R. *National Urban Transport Policy*; Ministry of Urban Transport: New Delhi, India, 2021. Available online: http://www.indiaenvironmentportal.org.in/content/254905/national-urban-transport-policy-2006/#:~:text=The%20objective%20of%20this%20policy,other%20needs%20within%20the%20cities (accessed on 12 October 2020).

56. Ministry of Urban Development, Government of India. *Ministry of Urban Development Government of India National Urban Transport Policy*; Ministry of Urban Development, Government of India: New Delhi, India, 2014. Available online: https://www.changing-transport.org/wp-content/uploads/E_K_NUMP_India_2014_EN.pdf (accessed on 12 October 2020).
57. Force, T. Task Force on Integrated Transport Policy. Available online: https://mohua.gov.in/upload/uploadfiles/files/TransportPolicy.pdf (accessed on 12 October 2020).
58. Capital, N.; Planning, R. *National Capital Region Planning Board*. 2013. Available online: https://www.ncrpb.nic.in/pdf_files/Rti_06_Nov_15.pdf (accessed on 12 October 2020).
59. National Capital Region Planning Board. *Ministry of Housing and Urban Affairs*; Government of India: New Delhi, India, 2021; pp. 1–38. Available online: https://proconsultant.tech/employer/ncrpbmohua/ (accessed on 12 October 2020).
60. Guhathakurta, P.; Sreejith, O.P. Impact of climate change on extreme rainfall events and flood risk in India. *J. Earth Syst. Sci.* **2011**, *120*, 359–373. [CrossRef]
61. Avinash, S. Flood Related Disasters: Concerned to urban Flooding in Bangalore, India. *Int. J. Res. Eng. Technol.* **2014**, *3*, 76–83. [CrossRef]
62. Report, W.D. *Place and Prosperity*. pp. 1–32. Available online: https://unhabitat.org/sites/default/files/download-manager-files/Gender%20and%20Prosperity%20of%20Cities.pdf (accessed on 12 October 2020).
63. Aggarwal, S. Do rural roads create pathways out of poverty? Evidence from India. *J. Dev. Econ.* **2018**. [CrossRef]
64. Broda, C.; Weinstein, D.E.; The, S.; Economic, A.; June, N. Product Creation and Destruction: Evidence and Price Implications Product Creation and Destruction: Evidence and Price Implications. *Am. Econ. Rev.* **2015**, *100*, 691–723. [CrossRef]
65. Paper, W. 2006. Available online: www.econstor.eu (accessed on 20 October 2022).
66. Kazianga, H.; Linden, L. The Effects of Girl-friendly Schools: Evidence from the BRIGHT School Construction Program in Burkina Faso. *Am. Econ. Rev.* **2012**, *5*, 41–62. [CrossRef]
67. PMGSY. Available online: http://omms.nic.in/ (accessed on 20 October 2022).
68. Extension of Services to the Agreement Signed between Ministry of Rural Development (MORD)-National Rural Roads Development Agency (NRRDA) and ILO partnership for the Pradhan Mantri Gram Sadak Yojana (PMGSY)-INDIA. Available online: https://www.ilo.org/newdelhi/whatwedo/eventsandmeetings/WCMS_468084/lang--en/index.htm (accessed on 12 October 2020).
69. TomTom Traffic Index. Traffic Index Traffic Index Results. 2018. Available online: https://www.tomtom.com/traffic-index/ranking/ (accessed on 20 October 2022).
70. Traffic Index 2018-Drishti IAS. Available online: https://www.drishtiias.com/daily-updates/daily-news-analysis/traffic-index-2018 (accessed on 10 October 2022).
71. India Tops Traffic Congestion Index with 4 Cities in Top Ten. Available online: https://www.nationalheraldindia.com/national/india-tops-traffic-congestion-index-with-4-cities-in-top-ten (accessed on 10 October 2022).
72. TomTom Traffic Index. Traffic Index Traffic Index Results. 2019. Available online: https://www.tomtom.com/traffic-index/ranking/?country=FR (accessed on 20 October 2022).
73. Traffic Congestion Ranking | TomTom Traffic Index. Available online: https://www.tomtom.com/en_gb/traffic-index/ranking/ (accessed on 10 October 2022).
74. Pope, C.N.; Bell, T.R.; Stavrinos, D. Mechanisms behind distracted driving behavior: The role of age and executive function in the engagement of distracted driving. *Accid. Anal. Prev.* **2017**, *98*, 123–129. [CrossRef]
75. Klauer, S.G.; Guo, F.; Simons-Morton, B.G.; Ouimet, M.C.; Lee, S.E.; Dingus, T.A. Distracted Driving and Risk of Road Crashes among Novice and Experienced Drivers. *N. Engl. J. Med.* **2014**, *370*, 54–59. [CrossRef]
76. Engelberg, J.K.; Hill, L.L.; Rybar, J.; Styer, T. Distracted driving behaviors related to cell phone use among middle-aged adults. *J. Transp. Heal.* **2015**, *2*, 434–440. [CrossRef]
77. Zhao, Y.; Yamamoto, T.; Morikawa, T. ScienceDirect An analysis on older driver's driving behavior by GPS tracking data: Road selection, left / right turn, and driving speed. *J. Traffic Transp. Eng. (English Ed.)* **2018**, *5*, 56–65. [CrossRef]
78. Gouda, A.A.; Masoumi, H.E. Sustainable transportation according to certification systems: A viability analysis based on neighborhood size and context relevance. *Environ. Impact Assess. Rev.* **2017**, *63*, 147–159. [CrossRef]
79. Resources | U.S. Green Building Council. Available online: https://www.usgbc.org/resources? (accessed on 18 October 2022).
80. BRE. BREEAM -C, a Green Rating Tool. Available online: https://bregroup.com/products/breeam/ (accessed on 12 October 2020).
81. Welcome to CASBEE Website! Available online: http://www.ibec.or.jp/CASBEE/english/index.htm (accessed on 18 October 2022).
82. USDM. *Abu Dhabi urban Street Design Manual*; USDM: Abu Dhabi, United Arab Emirates, 2013.
83. LEED for Neighborhood Development Credits, Prerequisites and Points | U.S. Green Building Council. Available online: https://www.usgbc.org/articles/leed-nd-credits-and-points (accessed on 18 October 2022).
84. Scoring and Rating. Available online: https://www.breeam.com/communitiesmanual/content/00_introduction/05_scoring_and_rating_proposals.htm (accessed on 18 October 2022).
85. Green, T.; Council, B.; Star, G. Green Building Rating Systems Around the World; Sustainable Retail Development. 2009. Available online: https://link.springer.com/content/pdf/bbm:978-90-481-2782-5/1.pdf (accessed on 12 October 2020). [CrossRef]
86. The Pearl Rating System for Estidama Community Rating System. 2010. Available online: https://www.academia.edu/41520072/The_Pearl_Rating_System_for_Estidama_Community_Rating_System_Design_and_Construction (accessed on 12 October 2020).

87. Litman, T. *Evaluating Active Transport Benefits and Costs*; VTPI: Victoria, BC, Canada, 2020; pp. 134–140. Available online: https://policycommons.net/artifacts/2066969/evaluating-active-transport-benefits-and-costs/2820998/ (accessed on 12 October 2020).
88. BRE Global | BRE Group. Available online: https://www.bregroup.com/about-us/bre-global/ (accessed on 19 October 2022).
89. Abu Dhabi Urban Planning Council | Söhne and Partner Architects. Available online: https://worldarchitecture.org/authors-links/pnhzv/abu-dhabi-urban-planning-council-sohne-and-partner-architects.html (accessed on 19 October 2022).
90. Lachapelle, U.; Frank, L.D. Transit and health: Mode of transport, employer-sponsored public transit pass programs, and physical activity. *J. Public Health Policy* **2009**, *30*. [CrossRef]
91. Varma, C.R.S.; Palaniappan, S. Comparision of green building rating schemes used in North America, Europe and Asia. *Habitat Int.* **2019**, *89*, 101989. [CrossRef]
92. GRIHA Rating | Green Rating for Integrated Habitat Assesment. Available online: https://www.grihaindia.org/griha-rating (accessed on 20 October 2022).
93. Green, I.; Council, B. Indian Green Building Council (IGBC). Available online: https://igbc.in/igbc/redirectHtml.htm?redVal=showratingSysnosign (accessed on 9 October 2022).
94. Hnxg, N. National Building Code 2016 (Volume 1). 2017, Volume 80. Available online: https://www.bsbedge.com/NBC2016 (accessed on 20 October 2022).
95. Singh, P.; Shankar, V.; Sinha, P.; Vijhani, A.; Pahuja, N. Author's Accepted Manuscript. *Int. J. Disaster Risk Reduct.* **2018**. [CrossRef]
96. What Is Smart City: Smart Cities Mission, Government of India. Available online: http://smartcities.gov.in/content/innerpage/what-is-smart-city.php (accessed on 30 October 2022).
97. Sharma, R.; Newman, P. Does urban rail increase land value in emerging cities? Value uplift from Bangalore Metro. *Transp. Res. Part A* **2018**, *117*, 70–86. [CrossRef]
98. Korzhenevych, A.; Jain, M. Area- and gender-based commuting differentials in India's largest urban-rural region. *Transp. Res. Part D* **2018**, *63*, 733–746. [CrossRef]
99. Aggarwal, P. 2 °C target, India's climate action plan and urban transport sector. *Travel Behav. Soc.* **2017**, *6*, 110–116. [CrossRef]
100. Oncology. 2020. Available online: https://experts.nebraska.edu/en/publications/covid-19-pandemic-and-its-effects-on-cancer-care-both-good-and-ba (accessed on 12 October 2020).
101. Cheng, X.; Long, R.; Zhang, L.; Li, W. Unpacking the experienced utility of sustainable lifestyle guiding policies: A new structure and model. *Sustain. Prod. Consum.* **2021**, *27*, 486–495. [CrossRef]