

Article

Analysis of Sustainable Transport for Smart Cities

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Abstract: For decades, transportation has been considered as a link to all aspects of life worldwide. In this case, the world's natural environment, social well-being and economic development all usually depend on transportation systems. In most cases, safe, clean, sustainable and equitable transport systems help countries, especially in cities and urban centers, to thrive. However, a wide range of research shows that transportation systems in most of the cities and urban areas are unsustainable. In fact, some of these transportation systems are considered to be a threat to the environmental, social and economical aspects of future generations. In this perspective, therefore, changing such trends in transportation requires the collaboration of various stakeholders at regional, national and international levels. In this paper, therefore, a wide range of definitions of sustainable transport are discussed. More so, some of the aspects of smart transport for modern cities such as cycling and the role of women in sustainable transport were explored. With the aim of getting to the core of the subject, cases of women in bicycle transport, especially in the Netherlands and Germany compared to Kenya and Uganda are equally elucidated. Although not fully outlined, the idea of smart cities and sustainable transport have heterogeneous characteristics globally as discussed herein.

Keywords: cycling; Germany; Kenya; smart cities; sustainable transport; the Netherlands; Uganda; women

1. Introduction

We discuss sustainable transport in its various forms. Herein an extensive review of definitions on the subject matter is carefully studied. The aim of the study was to analyze the concepts of sustainable transport and smart cities. Also, the study aimed at showcasing the global efforts towards achieving sustainable transport and smart cities, as well as gender issues such as cycling in respect to different parts of the world, as one of the examples of sustainable transport means.

Sustainable transportation exists as one of the primary gears driving development, a trend that has existed for a long period of time [1]. Köhler [2] speculates that sustainable transport is considered to be a global concept. In fact, most developed countries continue to invest in the physical environment such as infrastructure and mobility, which are considered to be core drivers for sustainable transport. Like never before, achieving sustainable development in smart cities requires the integration of reliable transport systems. The driving factor of smart cities is to ensure the connection of human capital, infrastructure and social capital in a bid to achieve a more sustainable economic development as well as a better lifestyle for residents in these cities. In other words, sustainable transport is one of the driving elements as far as achieving smart cities is concerned. In this case, the continued steady movement of resources, be it human labor or goods across given locations, leads to domestic and global prosperity.

In their research investigation, Rassafi and Vaziri [3] explain that economic growth necessitates flexible transportation which eases access to resources and trade markets. Furthermore, transportation is positively linked to better standards of life through connecting people to places of education, work,

health services, and recreation [2–5]. As such, transportation is a primary concept that actuates social and economic development. However, for such rewards, there are equally reproachable effects, and for transport, these include resource depletion, pollution and over-congestion [3]. As such, this necessitates the need for a stable form of transport that would reduce these spillover effects, being in the form of sustainable transport. Hence, sustainable transportation (Figure 1) is an aspect of global sustainability, which involves meeting present needs without reducing the ability of future generations to meet their needs [4,6,7].

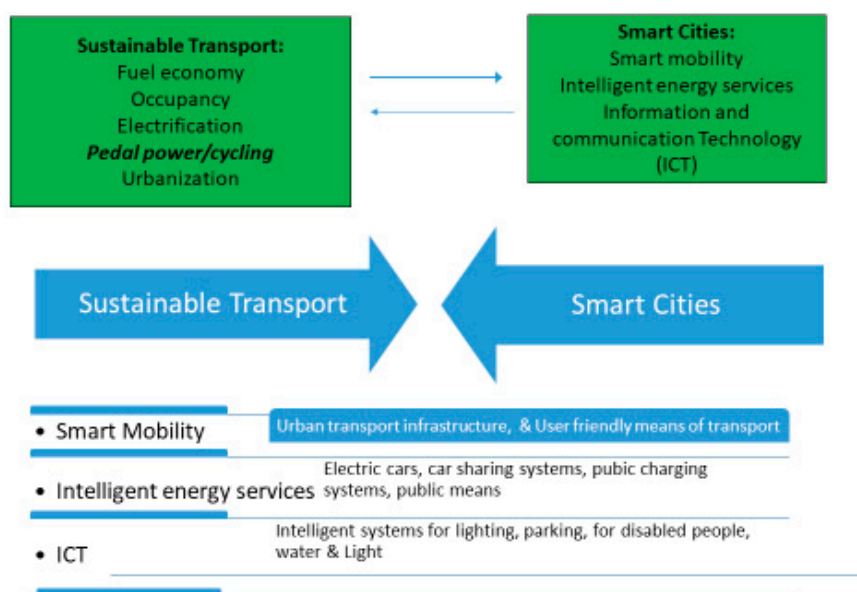


Figure 1. The inter-connection between sustainable transport and smart cities.

As indicated in the study conducted by Malasek [8], the idea of smart cities rotates around intelligent approaches (Figure 1) that focus on the needs and interests of people regarding economic development. Malasek [8] highlights that the concept of smart cities looks at the long-term element of economic development and quality of lifestyle of people living in cities. The idea is to provide improved and smarter public services, which are considered to be not only citizen-centered but also economically viable and sustainable.

In fact, there has been a number of definitions quoted for sustainable transport, but most relate to the environment, economy, and social equality [5]. Similarly, Zhou [9] stated that sustainable urban transportation would entail soliciting modes of transport that would not implicate human or environmental safety.

Furthermore, in the same report, Zhou [9] went on to further stress that the goals of sustainable transportation are aimed at providing mobility that safeguards regional economic development while at the same time ensuring long-lasting future for natural resources. As such in, its simplest of forms, sustainable transport would entail satisfactory to and from movement without negatively implicating the capacity of future generations. Also, the symposium on Sustainable Transport: Definitions and Responses [10], defined it as transport with a stable capital value, capital being of human, monetary, and natural value.

Transport Canada [7] also gave a detailed definition of sustainable transport consisting of three core values. First, such a system would be permitting of safe and consistent access to individual and societal basic needs, while securing both human and ecosystem health to ensure stability for future generations. Second, sustainable transport must have value for money through efficiency in operation and affordability, while offering various alternative transport means to choose from such as road and cycling routes, public buses and trains. Third and finally, the report vehemently revealed that emissions control and global waste management would be the core goals of sustainable

transport. In fact, Transport Canada [7] further expressed the role of such a transport system in limiting the consumption of both renewable and non-renewable resources. Consequently, this would be attained through operation components of sustainable transport that would allow for justifiable resource use, recycle and reuse, control of land use and noise pollution. Ultimately, only through careful consideration for safeguarding the environment, society, and economy can this much sought after sustainability be achieved.

Scholl et al. [11] further defined sustainable transport as a form of transportation where consumers would have to pay their full social costs, including those that would have been paid for by future generations. Actually, this was parallel to Friedl and Steininger [12], who stated that sustainable transport would have to account for the future. In fact, through careful projected estimates of future generation preferences, evaluation of cost-benefit analyses of transport volumes and modes would ensure that the net-benefit of the transport did not decline. To proceed, Scholl et al. [11] further stated that sustainable transport would demand changes in energy use in transport because it increases CO₂ emissions. This, therefore, would be achieved through careful maintenance of production opportunities for the transport sector [2]. However, there are rather common cases where it is impossible to substitute natural capital stocks with manmade alternatives. In this case, careful steps should be taken to ensure sustainability [13]. Consequently, the underlying result to ensure sustainable transportation would entail a reduction in the energy and material needs required for transport [14]. Entirely, this would therefore stem in streamlining land use patterns, thus reducing any resulting societal need for energy-intensive forms of transport [11].

In discussing sustainable transportation, Zhou [9] stated that early focus was overtly placed on environmental degradation, and exhaustion of resources resulting from the usage of petroleum. Evidently, unsustainable forms of transport are those that directly cause harm to the environment, in both short- and long-term estimations [6]. More so, Zhou [9] argued that sustainable transportation in a way was vehemently brought forth following growing public unease over global warming, primarily after the effects of motor vehicle emission. As such, sustainable transport would entail an enhancement of vehicle fuel efficiency to reduce the amount of fuel consumed, thus lowering resulting emissions. Therefore, reducing CO₂ emissions partaking to road transport through the use of low emission trucks and presenting incentives for less polluting transportation modes is a core value of sustainable transport [9]. To elaborate, examples of less polluting transportation modes popularly adhered to in the sustainable transportation model include walking, cycling, and sailing. Zhou [9] gave a number of other strategies, apart from reducing CO₂, that have been adopted across the world to actuate sustainable transport as mentioned here. First, in Europe, the European Conference of Ministers of Transport (ECMT) promoted improving road safety, traffic management, marketing and telematics as a tool to enhance public transport. Furthermore, they aimed at improving the competitiveness of road transport alternatives such as trains. Also, in Canada, improvements were made to enhance the performance of carriers and operator services. Actually, this was achieved through increasing the decision-making capacity of government offices mandated with management of the transportation sector, thus bettering the management of Transport Canada operations [9].

In the USA, a number of government organizations have been mandated with the realization of sustainable transport, and through them, a number of approaches have been adopted. For one, transportation planners were granted strict operational freedom to cultivate the culture of sustainable transportation in the country [2]. Furthermore, the transportation sector was provided its own operational budget and a steady funding base to ease operation while scrupulously paying attention to accountability, thus easing transportation planning [9]. However, there has been a number of barriers that have limited sustainable transport across many countries in the world, as elucidated here. Transport Canada [7] stated that most decision making campaigns have been biased to promote already present unsustainable transportation types. Secondly, the common misconception that sustainable transportation would be economically unfeasible has further limited the successful implementation of the policy. Third and finally, the issue of soliciting a working and acceptable alternative to oil or petroleum is a major challenge, given

that the suggested alternatives also implicate environmental stability. Nonetheless, sustainable transport clearly is the answer to the rather lacking present transportation entities in the world, thus suggesting strong opportunities for its wholesome adoption in the future.

Sustainable transport is one aspect of achieving smart city status. Both terminologies have a lot in common in terms of elements and outputs. They both aim at achieving better living conditions for urban communities (Figure 1). Therefore, our study discusses this interconnection of smart cities and sustainable transport. Also, a significant focus was given to cycling as an approach for sustainable transport and smart cities with cases of women cycling in the Netherlands and Germany compared to Kenya and Uganda.

2. Materials and Methods

The study employed a content analysis technique [15]. This is considered to be a complex research approach practice that aims at exploiting, analyzing and coding numerous words of textual data, thus attaining valid replicated inferences [15]. In this study, content analysis was used as an approach to comprehend message content as the basis from which inferences and conclusions about sustainable transport research are drawn. More so, this method was unique in authenticating authorship, and this usually allowed one to determine authorship through correlating the frequencies of nouns or function words following thorough examination of prior writings by disagreeing authors [15,16]. While reviewing literature, a wider range of internet sources were searched by entering keywords in popular search engines, scientific data banks such as Web of Science, Scopus and ScienceDirect among others. In a bid to easily access materials on the subject under study, the researcher used various keywords such as 'sustainable transport', 'smart transport for modern cities', and 'smart cities' to mention but a few. At this point, this method was used to analyze written literature material on sustainable transport in smart cities. In other words, content analysis methodology was used to analyze a wide range of content in the subject while applying text evaluation techniques [15]. Being one of the popular research methods adhered to for a multiplicity of disciplines, it was considered to be a reliable approach for this investigation.

Furthermore, this methodology helped in availing knowledge, and fresh perceptions on sustainable transport for smart cities. At this point, this was done through objective representation of facts collaborated with holistic courses of action. In this way, the transparency in this research method presented the researcher with high level of abilities to formally summarize content within written content. More so, this was coupled with competence for comprehending the author's perceptions of that material. In this case, therefore, content analysis allowed the researcher to understand the intended message from several literature materials on sustainable transport through deriving rational, and replicable assumptions [15].

Also, the study analyzed several cases of bicycle cycling transport from all over the world in terms of geographical location, but mainly Europe and Africa. These involved women in another case in the Netherlands, Germany, Kenya, and Uganda. Global perspectives were also captured and discussed extensively. Both approaches are qualitative in nature [17]. Also, qualitative investigation methods have main essentials of narrative research, phenomenology and case studies among others.

3. Literature Studied

3.1. Smart Transport for Modern Cities

The ever persistent trend of global development has primarily been a result of progressive infrastructure development to meet the constantly evolving modern demands by any given population. In fact, it is imperative for any given modern city to sustainably develop transportation systems to further advance any intended prosperity. Rassafi and Vaziri [3] stated that infrastructures solicit critical public services, essential for economic development and improved standards of living. More so, the same report reveals that a majority the global populated cities contribute a staggering 80% to

global GDP (Gross Domestic Product). As such, this therefore affirms without a doubt that these modern urban cities to a large degree are the cornerstone on which global development is hinged. However, there comes risks of such large numbers primarily in the form of transportation. To elaborate, Dia [7,18] stated that traffic congestion costs an average of 1–3% of a country's GDP while the global road fatality rates soar at 1.2 million and cost USD \$100 billion per year. Ultimately, modern cities have gone the extra mile to establish smart transport systems to enhance the flow of urban traffic better while improving the mobility of their inhabitants. Recently, it has become a trend for many modern cities to transition into the digital age through purposeful integration of information and communication technologies into transportation and administration at large [7,18].

In truth, the underlying goal behind the establishment of a smart transportation system for any modern city is to avail effective energy efficient modes of mobility for inhabitants while reducing transport-related carbon emissions. For example, Transport Canada [7] stressed that modern transportation systems are entailed with high consumption rates of both renewable and non-renewable resources. Also, Zhou [9] affirmed the need for smart transportation as resulting from the impeding threat of global warming, primarily contributed to by motor vehicle emissions. Ultimately, therefore, smart transportation enriches simple in-city journeys, while improving the quality and services of transportation within any given modern city. Hirst [19] also expressed the fact that smart cities are seeking to become 'smarter' by developing sustainable transport systems. sustainable transport involves planning and coordination of all mobility organs that are buses, trains, and traffic lights to mention but a few. Accordingly, this is corresponded by dissemination of live travel information to peoples' smartphones to provide a personal touch that improves passenger experience while reducing any potential issues. More so, the study conducted by Olaverri [20] also stated that smartphone applications could be a communication platform to inform pedestrians and vulnerable road users on public transport systems about their destinations thus eliminating risks. Furthermore, the United Nations Commission on Science and Technology for Development [21], was of the view that modern city transportation must evolve to become smarter so as to account for the ever growing and demanding population.

More so, the study further revealed that the fundamental mass transit systems for a number of modern cities are trains, subways, and buses. To elaborate, in Singapore, the Mass Rapid Transit (MRT) is the nation's flagship smart transportation transit solution to the demanding masses. While looking at the numbers, the system's efficiency sees over 2.5 million people from the nation's total population of 3.5 million using its services daily. In fact, over 100 stations in Singapore use MRT, with trains having 5-minute intervals between each other. Thus, subway and train systems are a fundamental smart transportation feature for many modern cities, with regular improvements being made to the system annually on a global scale.

On the same note, Olaverri [20] further stated that vehicle-to-pedestrian and pedestrian-to-vehicle information systems are ultimately aimed at improving road safety by issuing warnings to application users on impeding collision risks. In this case, this form of road safety campaign has been vigorously researched, with most of the modern cars being equipped with motion detection softwares together with automatic braking systems. Likewise, Sugimoto et al. [22] explained that most of the invented wireless local area connection communication systems are used to alert pedestrians, thus warning them of collision risk.

Cycling is a common form of smart transportation commonly practiced in modern cities. In many countries, public bicycle systems under local governments or non-governmental organizations have been set up to share bicycles amongst inhabitants. Hirst [19] associated cycling with reduced traffic congestion, considering cyclists have individual cycle lanes. Also, the same report affirms that cycling reduces pressure on public transport, while improving the individual health of inhabitants who regularly use this mode of transportation. In the same light, Banks [23] revealed that over half of the inhabitants in Copenhagen commute by bike. As such, to support this, over 380 smart traffic signals have been installed all over the city to give cyclists first priority to speed up their mobility

times through traffic. Hence, Copenhagen achieved a 10% reduction in travel times through cycling, a common trend steadily catching on through the whole nation at large [24]. Similarly, the United Nations Commission on Science and Technology for Development [21] also stated that in Budapest, a cycling network consisting of 98 stations to rent and over 1000 bicycles was established with a success rate of over 1 million rentals.

In truth, modern city traffic is significantly composed of large vans and delivery trucks doubling the routine of carrying goods and products between a multiplicity of stores and shops, a strenuous routine [19]. Thus, therefore, smart transportation offers remedial alternatives such as the exploitation of rail systems and water freighters to transfer and distribute products on demand to different modern cities. Ultimately, through cycling and electric vehicles, these goods are then supplied to individual households. In this case, smart transportation helps smoothen trade. Hence, smart transportation systems have been generally attributed with positive rewards in the different modern cities where such projects have been implemented. Hirst [19] similarly revealed that implemented smart transport measures in the United Kingdom were provided an investment for energy efficiency and waste management development under the European Union Cohesion policy estimated at £100 million for London and £100 million for North West England respectively.

Furthermore, the same report stated that the wireless electronic parking permit system, a particular form of smart transportation implemented in a section of New York saved the government a massive USD \$8 million from a mere USD \$50,000 investment. Similarly, Banks [23] found out that over 380 smart sensors were installed in Copenhagen to ease mobility for the large cycling faithful of the city. In this case, the sensors detect a group of cyclists headed towards a busy intersection, then signal the traffic lights to turn green thus allowing them safe passage through. More so, the sensors went on to study the cyclist's speed data based off recordings from camera, then adjusted the timings of the lights to further increase travel time. Primarily, he was of the view that enhancing mainstream traffic lights systems with digital sensing and communication technologies lessened traffic delay times by over 40%. In this case, this enormous improvement was attributed to the digital feature that allowed cars to be the control panel for the traffic light, unlike the traditional opposite. Thus, traffic lights have a fundamental role in actuating smart transportation for modern cities.

Also, traffic control systems are designed to account for public transport priority as a form of smart transportation for modern cities. In this case, a report for the European Union by CIVITAS [25] revealed that traffic control settings are implemented to allow for less stops by buses at traffic lights. In fact, the traffic systems are programmed in such a way that signal priority to buses does not to a large degree negatively impact traffic flow of other road users such as cyclists and pedestrians. To actuate this, CIVITAS [25] stated that two approaches are adhered to for fluid implementation of public transport priority. First, the passive control system allows for public transport vehicles to smoothly move without stopping, thus bypassing the system easily. Second, for the active system, traffic light signal timing is adjusted in real time based off the expected arrival of the desired public transport vehicle at the intersection, hence this is the more vigorous form of the system. To elaborate, such systems have been implemented and actively used minimally in Toulouse in France, with future options for full integration citywide. Ultimately, the results revealed a significant 52% reduction in waiting times at traffic lights for public transport systems, thus a successful smart transportation module for modern cities.

Benevolo et al. [26] also stated that technological advancements have allowed for the development of hybrid cars and car-sharing as similar examples of smart transportation for modern cities. In fact, as a core underlying value of smart transportation, hybrid vehicles that partly alternatively use electricity, would allow for reduced emissions resulting from motor vehicles. Also, the car-sharing social platform works through allowing inhabitants of modern cities to reserve vehicles of choice, driving it and returning it from the point of picking while incurring a reasonable fee for service costs. Ultimately, Benevolo et al. [26] affirmed that this form of smart transportation kills two birds with one

stone through allowing for emissions control while at the same time reducing traffic congestion in modern cities.

Also, another form of smart cities sustainable transport particularly on the rise is the use of electric vehicles, with accommodations being made through widely spreading charging points across modern cities. Actually, the European Union White Paper on Transport estimated that all modern European cities would be rid of traditionally fueled motor vehicles by 2050 [27]. Also, in the same light, Olaverri [20] elaborated that another smart cities sustainable transportation approach is the use of autonomous vehicles. More so, this was similar to Dia [18] who stated that this is still a work in progress. Nonetheless, it offers a lot of positives for modern cities. To elaborate, autonomous vehicles allow for uniform, streamlined traffic flow through the use of sensors which will account for vehicle spacing while maintaining safe distances between each vehicle. At the same time, this will all be achieved with lowered vehicle energy demands through limiting the impact of vehicle aerodynamic on consumption.

Smart cities sustainable transport systems have been vehemently adopted by a number of modern cities which have invested in the use of internet technology to enhance the functionality and dispersal of service to inhabitants, thus evolving into smart cities. Giffinger et al. [28] defined a smart city as a well-performing metropolis built on the smart combination of endowments and activities of self-decisive, independent and aware citizens. In one way or another, this purposely aims at elucidating the fact that a multiplicity of industries in any such city adamantly merges information and communication technologies (ICT) in their day to day modern transport platforms. In the same regard, the report further implicates smart cities as propagators of quality smart transportation regimes through adherence to new modern modes of mobility. To elaborate, it is common for inhabitants to regularly cycle to places of convenience, as cycling lanes and bridges are clearly elaborated [21]. Furthermore, it is popular for inhabitants to use electric cars or take bullet trains owing to the highly developed metro systems [29]. However, the use of smart transportation modules has similarly been met with a number of hindrances such as over prioritizing one form of road user over the other, causing longer waiting times. Also, for example, to rigorously support cycling, there is a need for infrastructure development such as building cycling lanes and bridges to accommodate this smart transportation, funding which might not come cheap for many cities. Nonetheless, smart transportation offers flexibility and greener transportation alternatives for a multiplicity of modern cities thus a great necessity.

3.2. Cycling for Sustainable and Smart Cities

Cycling is among the most popularly practiced forms of smart and sustainable transport across many nations in the world [30]. In a way, this is an account of the flexibility and smoothness in mobility offered by cycling, while lowering traffic congestion, a common trend for smart cities. In fact, cycling is a cheap and easygoing form of mobility within and around smart cities [31]. Hence, public bicycle systems where inhabitants are allowed to share bicycles continue to be one of the common trends for numerous smart cities. For example, Poppe [32] revealed that over 39% of total distances covered in Munster is as a result of cyclists, and thus the city is dubbed Germany's capital of bicycles. As a matter of fact, the number of people in Munster who prefer to use bicycles for mobility increased from 29.2% to 39.1% as of 2013, much higher than those who opted for vehicle at 29%. Moreover, a whole town in Munster, Promenade, is purposely set aside for cyclists, and home to a grand bicycle stage of over 3300 bikes.

On the same note, Larsen [33] stated that around 500 cities worldwide practice bike-sharing programs which together provide 500,000 bicycles to inhabitants. Todhunter [34] also revealed that Copenhagen has an extensive system of cycle paths spanning over 400 km, prompting a majority of the city's population to exploit this. Hence, over 40% of Copenhagen's inhabitants travel to work using bicycles, which was similar to Banks [23] who stated that about half of Copenhagen's population commute by bike, thus making cycling a big deal for smart and sustainable cities in the world.

Copenhagen, being a smart city [35], obviously requires smart solutions to the ever-growing transportation demands from inhabitants [36]. Following this, the city deliberately planned to ease transportation while limiting traffic congestion through establishment of a complex bicycle lane system. Thus, therefore, the city is globally recognized as the best city for cyclists, following its rigorous development towards the cycling industry [34,35]. More so, Copenhagen's cycling system and structure has been used as a template to improve transportation in other cities across the world. Say, Lanza [37] stated that these policies have been steadily implemented into Mexico City's vast transportation network through allowing for cycling support.

Larsen [33] also revealed that it was observed on Sundays in Mexico City that over 15,000 cyclists cycle in unison through the city while following along the established cycle lanes in the city. Mexico City is among the worst affected cities in the world as resulting from traffic congestion with the average rush hour speed of a car being 4 km/h [38]. The same report extensively states that Mexico City has since introduced a bicycle sharing system through ECOBICI (Eco Bikes sharing system) while introducing over 170 kilometers of cycling lanes and hubs to further support cycling. ECOBICI received considerable public attention with over 265,000 registered users and about 35,000 daily trips cycling trips by inhabitants of Mexico City, with a recorded increase in bicycle trips of over 500%.

Graham and Zhang [39] further stated that public bicycle systems have significantly grown in popularity and implementation over the years, with more than 50 countries using the system. It is to be observed that China is the global leader of public bicycle systems, with about 80 systems actively in use in the country totaling to about 400,000 bicycles available for cycling [30]. Bicycle sharing entails availing bikes to the public thus allowing for inhabitants to take bicycles from the parks, commonly known as a docked station, and after using, returning it to other stations [40]. Bike-sharing allows for flexibility in transport for sustainable and urban cities, thus a fitting addition to the expansive public transport systems of these cities. Larsen [33] was of a similar view on bike-sharing systems by further stating that it has prompted people to view car ownership as a bother following rush-hour congestions. The report went on to elucidate that bike-sharing was the fastest growing mode of transport in the world responsible for raising the cycling flag high. Zhang et al. [40] further went on to state the benefit of cycling as opposed to other forms of transport. In truth, it is less expensive to facilitate bicycles in major urban cities, let alone the small cost of owning a bike. Bikes can also be used to access hard to reach places for popular transportation forms, thus making cycling an ideal transport mode for ill accessed regions.

In this case, this can entirely be down to two reasons, the first being that bicycles occupy little space and are hence easy to navigate, and also the expansive cycling lane systems which make it easy to reach such places. Marqués et al. [41] were of the same view after they observed an increase in the number of cyclists in Seville following the growth of isolated cycling lanes for the period 2006 to 2011. Resultantly, the number of people whose commute was by bike surged considerably even though Seville had no prior history of cycling. Hence, sustainable and smart cities must have necessary infrastructure development to readily accommodate cycling for it to have full prosperity.

More so, Larsen [33] stated that these lanes spread vast bicycles networks easily linking popular locations. Copenhagen, the world's cycling capital, went a step further as to incorporate a number of sensors along cycling lanes to further boost the efficiency of cycling in the city [23]. In effect, therefore, traffic lights are prompted to turn green once the sensors notice an influx of cyclists along cycle lanes on busy intersections, thus giving them safe passage. These lanes not only allow for reduced traffic congestion but also offer safety to the majority of cyclists in any one of these sustainable and smart cities, given the fact that traffic flow is relatively high. Marqués et al. [41] also stated that segregating cyclists from general motorized traffic made cycling in Seville not only safe but also easy and comfortable for everybody. For that reason, cycling lanes offer safety to cyclists while ensuring fluid connectivity between a number of locations in sustainable and smart cities, thus a critical necessity for prosperous cycling.

Most modern cities are ultimately designed to be traversed with cars. In this case, therefore, planning is made largely for large distances, hence mobility of using bicycles is hard in such cities. It is beyond doubt that most of the urban plans for sustainable and smart cities largely center on cars as the primary form of transportation [40]. Hence, it is imperative for any given city venturing into cycling to invest a considerable amount of effort and wealth in establishing necessary infrastructure that secures safety while allowing for efficiency [31]. This security has been offered by the cycling lanes and bike-sharing systems which always puts cyclists first as the center of traffic on roads in these cities that staunchly practice cycling.

Larsen [33] revealed that theft and vandalism had hampered the success of cycling for a number of cities, but the modern bike-sharing systems offered remedial solutions to this problem. In most cases, the mode of operation and management of bike-sharing systems has purposely over time evolved to account for securing the safety and durability of their merchandise. Gasiorowski [38] also stated that cycle parks account for anti-theft through using lock mechanisms on their bikes that lock the bicycle frames to cycle parking stands thus securing the bike.

On the same note, Larsen [33] highlights that modern bicycles popularly used in the bike-sharing systems are specially made from unique material that would fetch little to no value if stolen and sold by a thief. Furthermore, other bicycles come equipped with GPS trackers which emit radio frequency, allowing for constant monitoring and tracking, thus prohibiting theft. More so, the fact that the only way of accessing a locked bicycle for most systems is after payment by credit card payment or use of membership smartcard ensures safe storage for these bikes. It is common for a majority of systems to allow the rider a specified period of use following payment. Hence, the cyclists can select bicycles from the securely placed bicycle racks or docking stations and return them back after the user's time has expired. In this case, it is not surprising that research indicates that bike-sharing continues to experience the fastest growth as one of the modes of transport [33].

Traffic congestion is a serious global issue, with a number of major world cities succumbing to it in one way or the other. In this case, many people opt to use bicycles as a quicker mobility option. Gasiorowski [38] speculates that a multiplicity of urban cities are plagued with traffic congestion, with cycling offering a remedial solution to this issue whilst improving the health of the cyclist. In Annecy, France, a great percentage of in city trips are made by bike, which is affordable unlike cars and are thus owned by the majority of the population.

Also, given the fact that modern cities are space sensitive, bicycles take up less space than cars, and their parking is much easier and convenient. Truthfully, a cyclist will park their bicycle at a bike-stage close to their destination as opposed to vehicle parking slots which are hard to come by. Gasiorowski [38] further implicates cycling with better and improved health of cyclists since it is a reliable source of physical exercise. Indeed, cycling improves cardiac health through allowing for regular muscle exercise, along with expanding lung capacity, thus generally improving population health. Todhunter [34] was of the same view as far as the contribution of cycling to health is concerned. The more people ride, the more chances they stand to be healthy *ceteris paribus*.

Pinna et al. [42] observed a surge in the use of bicycles by inhabitants of major Italian cities. Consequently, the report revealed that cycling was very popular in northern Italy with a number of cycle lanes connecting a number of different locations within these cities. Furthermore, bike-sharing programs were also seen to have expanded recently from one city in 2005, Bologna, to over nine by 2010. In truth, the report vehemently expresses the fact that ongoing plans are already in place to further extend bike-sharing schemes to other cities across Italy as per directive by the Italian national government. Also, Pinna et al. [42] explained that the number of bikes available for cycling in these bike-sharing cities significantly increased.

In truth, sustainable transport such as cycling has a lot to offer to most smart cities across the globe. For example, efficient cost-friendly mobility routines usually offer easy connectivity within and around smart cities. However, there is a need to scrupulously adhere to a number of measures to ensure a prolonged actively functional cycling culture in sustainable and smart cities. Poppe [32]

stated that it was crucial for cycling lanes to have high connectivity even to the city while operating separately from main roads to ensure utmost safety. Furthermore, it is important for the traffic lights systems to be bike-friendly, with the ability to detect cyclists along busy streets and intersections, signposts along roads. Finally, there should be bike management facilities and parks.

Nonetheless, cycling continues to be one of the most common transportation means across the globe that comes with a range of health, social and environmental benefits. In fact, Garrard et al. [43] highlighted that cycling is an active mode of transport that most developed countries continue to harness and use. However, Garrard [44] explained that cycling among women in some countries is still limited because of substantial gender differences. According to Garrard et al. [45], cycling among women has always contributed to their social inclusion since it offers them an affordable and at the same time convenient mode of transport. [43] claimed that in most European countries, women cycle more frequently than men. In most cases, traffic safety usually acts as bottlenecks for women to fully participate in cycling.

In the study conducted by [43,46], most developed countries, such as the Netherlands and Germany to mention a few, provide on-road as well as off-road bicycle facilities, which in one way or the other address most of the potential constraints for bicycle users. Besides, Sarkar et al. [46] speculated that bicycle sharing systems have helped most women in developed countries frequently cycle than men. In this case, it is not surprising that cyclists in most developed countries such as the Netherlands comprise virtually all segments of people. In most African countries, bicycles are considered to be the most common means of transport used to link between villages, markets, and highway road networks. However, women are still limited when it comes to cycling, and this is attributed to gender differences in most parts of Africa. In this perspective, it is not surprising that the adoption of cycling among women in most developing countries is still low despite the steady flow of bicycle donation from Western countries.

3.3. Role of Women in Sustainable Transport

A wide range of researches indicates that women are underrepresented in sustainable transport, especially developing countries and a few Western cities [4,47]. While sustainable transport has the potential to bring out inclusive growth in the job market since women's participation is still limited in most countries. In fact, Teschke et al. [48] explained that sustainable transport is still out of reach for most women, especially those living in rural communities. According to the United Nations Global Sustainable Transport Conference [1], millions of people, women in particular, are still failing to commute long distances when going to work. Even though the transport is available, some women find it difficult to use most of the public transport because of security reasons. In this case, the United Nations Global Sustainable Transport Conference [1] highlighted that sustainable transport must be a teamwork project that includes both men and women. More so, United Nations reports indicate that sustainable transport is directly related to the achievement of development goals for women because it is one of the core elements of modern development.

In India, Singh [49] explains that women and girls are considered to be almost 50% of the urban population. However, Singh's [49] research indicates that more than 80% of women in India use public and non-motorized models of transport while going to work. More so, more than 70% of women in urban areas in India have sustainable transport. In this perspective, it is worth mentioning that transportation helps women to access both economic and social opportunities to thrive in their careers. More research highlights that in the years to come, most cities will need to implement inclusive sustainable transport that gives women a chance to participate like their counterparts [1,47,49].

According to Kronsell et al. [6], the role of women and transport has attracted the attention of many city leaders across the globe. However, studies indicate that there are various factors that affect women when it comes to public transport [48]. As a result, many countries have allowed women to participate in finding better solutions for sustainable transport. Based on the United Nations Global Sustainable Transport Conference [1], there is a great link between women, transport and employment

patterns in most urban areas. In other words, sustainable transport systems are considered to be the fulcrum, which allows most women in various cities to participate in the economic development of their countries. As much as this remains true for most smart cities, most women in some countries such as India rely heavily on public transport or walking. Nonetheless, women continue to play a significant role in transport policies and systems despite their limited level of participation. Therefore, it is not surprising that the United Nations Global Sustainable Transport Conference [1] recommends an inclusive approach for sustainable transport in various countries, especially in urban centers.

In the study conducted by Kunieda and Gauthier [50], women play a critical role in current transport infrastructure. In most cases, women are always concerned with the safety and personal security element of transport. In this case, women have been the source of policies that drive sustainable transport in most cities. More so, Kunieda and Gauthier [50] explained that better transportation systems have always contributed to people's quality of life in a given society. In this case, allowing women to participate in policymaking, especially on sustainable transport, has brought economic growth and efficient transport systems in most cities.

In their research investigation, Root et al. [51] explained that women are in various ways forming a large proportion of population, especially in most cities. As a result, they are playing a big role in modern cities through influencing transport policies. While looking at micro level, women have always had different travel patterns from men [51]. Based on the increased complexity of lifestyles and the travels most women take in modern cities, Grudgings et al. [48] speculate that the traditional transport approach should be rethought. Like never before, most of the emerging issues regarding women and transport have continuously influenced innovative ideas as far as sustainable transport is concerned. On the same note, one of the core elements in the increased modernization of transport is the experience enhanced by the mobility of women. In this perspective, it is not surprising that [51] highlighted that the travel patterns of women have improved like never before. In countries such as the USA, UK, and other developed countries, there has been an increase when it comes to the number of women regularly on the road [45].

Furthermore, Root et al. [51] speculated that this change is largely attributed to the changing role of women in various societies, especially in modern cities. According to Kronsell et al. [6], most of the modern cities are experiencing a significant increase in the number of women entering the workforce. As a result, this has increased the roles or importance of women in the process of making transport policies. More so, it is worth mentioning that the increasing number of women on the road has a great implication on the sustainability of transport based on these policies. In other words, there is no doubt that an issue of women in terms of the approaches in which transport policies are devised cannot be ignored. In his study, Buckingham [52] depicts that involving women in sustainable development is one of the key elements that can help change the world based on the level of new demands. In this perspective, transport cannot be ignored in any level of sustainable development. It is from such a background that [10] paints that the role women have in sustainable transport is increasing in one way or the other.

In the past decades, Kronsell et al. [6] explained that women used to travel less far compared to men in most cities, especially in the UK and USA. However, their patterns of travel have changed due to the nature of work women do these days. In fact, women compete with men in the job market, and this requires them to travel every day going to and from the workplace [31]. At this point, therefore, the role of women in sustainable transports, especially through policymaking, has increased in both developed and developing countries. More so, the shift to modern sustainable transportation infrastructure across the globe has affected women in various ways. For example, women struggle with men in the process of decision making when it comes to sustainable transport policies [53]. However, some countries, especially developing countries, still limit women from doing more on the issues that affect them such as sustainable transport.

Despite the improvements in travel patterns and the role of women in sustainable transport, their contribution is still less compared to men [53]. For example, women still tend to have shorter

commutes, especially in terms of time traveled and distance. As a result, this continues to limit their influence in policies that can favor them in one way or the other. As Root et al. [51] posited, the limited participation of women in sustainable transport is often explained while looking at the aspects of socio-economic issues they face. For example, most women in various countries still have access to private vehicles, and others are overwhelmed by domestic work. In this case, such circumstances limit them from playing bigger roles in the process of formulating sustainable transport policies that can transform their cities like never before.

According to Aljounaidi [53], women still have less control over resources, and this usually limits them from accessing private means of transport. In Gaza and Yemen, for example, Aljounaidi [53] explains that most women still struggle to use public transport despite the challenges amidst the services. Some of the challenges women in Yemen and Gaza face as far as transport is concerned include costs, timing and routing. In addition, most women who live in rural areas usually find it challenging to access sustainable transport while going to and from work. Just like Aljounaidi [53], AFCAP [54] explains that most governments in developing countries are working hard to promote the role of women in the transport sector. In countries such as Ghana, women are getting involved in providing transport related services, and some are appointed as managers at different levels. Nonetheless, studies indicate that women's involvement in sustainable transport is generally still low because of several reasons [53,54]. For example, most women lack enough money to afford to pay for services or buy their own vehicles. In fact, this explains why there is a higher incidence of walking to work among women compared to men.

Furthermore, AFCAP [54] paints the transport sector as one of the sectors that are most gendered in many of the African countries. In fact, most commercial drivers, people involved in transport management and bus conductors, to mention but a few, are male. According to Aljounaidi [53], social factors, which are imposed on women's mobility in most of the African countries are so high that they always impact on the role of women when it comes to transport infrastructure as well as services.

4. Cases of Women in Bicycle Transport: The Netherlands and Germany Compared to Kenya and Uganda

This section explores how the Netherlands, Germany, Kenya and Uganda have made bicycling among women a possible or inconvenient, and practical practice to move around their cities. The analysis relies on the available information collected from a wide range of online databases, and mostly scientific sources such as Scopus, Web of Knowledge Information collected on each of these case studies highlights the key factors helping or affecting levels of cycling among women as one of the factors facilitating sustainable transport and smart city options.

4.1. Case of the Netherlands

While reflecting on the study conducted by Pucher and Buehler [55,56] and Harms et al. [57], the Netherlands remains one of the most famous countries known for its high levels of cycling. According to BBC Magazine [58], most cities in the Netherlands have high levels of cycling compared to other countries across the globe. In this case, the success of cycling in these countries usually depends on favorable policies implemented by governments. For example, Pucher and Buehler [56] speculated that the Dutch government motivated various companies in the country to pay people to cycle while going to work. More so, the same research shows that the government encouraging cycling in a bid to fight congestion on the roads. Cycling infrastructure is one key element that has enabled the Netherlands to embrace cycling as a sustainable means of transport (Figure 2). The Netherlands also has parking structures for bicycles on all the bus stations, railway stations, and most buildings across the country. Cycling culture in the country is very developed, with less stereotypes attached to gender or age. Women and children embrace riding whether it is raining or shining [55,56,58].



Figure 2. Cycling in the Netherlands—Deventer City.

In their study, Pucher and Buehler [59] depicted that Dutch and other western countries take cycling to be practical and utilitarian. In fact, it is not surprising that there are more bicycles in the Netherlands than residents, especially in cities such as Amsterdam and Hague. BBC Magazine [57] indicated that more than 70% of the journeys made by men and women are by bicycles. It is such sustainable transport approaches that continue to help the Netherlands to have smart cities. Cycling for both men and women and integration of technology are enablers of smart city transport measures.

For both men and women, Pucher and Buehler [56] added that most cities in the Netherlands lead the way as far as cycling is concerned. For example, it is estimated that there are more than 22 million bicycles in the country. Surprisingly, there are about 17.1 million people who live in the Netherlands, and more than a quarter of the people cycle to work. Women participate equally with their male counterparts when it comes to cycling. Pucher and Buehler [56] painted that since 2005, the number of bicycles in the Netherlands has increased by more than 10%. In Amsterdam, for example, it is indicated that 32% of men and women journey by bike. More so, the government of the Netherlands implemented financial rewards in a bid to motivate people to cycle frequently. However, after the financial rewards stopped, many people continued to cycle, especially when going to work. It is worth mentioning that cycling has helped employees in the country to maintain good health as well as flexibility in their movements especially in and around the cities.

4.2. Case of Germany

In Germany, Cycling Monitor Germany indicate that 77% of people have used a bike in their daily lives, especially during leisure time [59]. In the same research, 13% of people living in Germany use a bike as a mode of transport on a daily basis. According to BMVI [59], cycling in Germany is booming like never before. In fact, both men and women are encouraged to use bikes as their mode of transport to reduce the traffic as well as for health benefits. More so, BMVI [59] explain that cycling in Germany accounts for an increasing share when it comes to transport, and this has provided a positive impact on the environment and health of people, as well as good climate.

With the aim of encouraging many people to switch to cycling, Germany is promoting cycling among men, women and the youth [59]. For example, it is indicated that Germany has improved

express roads for cycling to make it easier for everybody to cycle, and this contributes to achieving ‘smart city’ status. As BMVI [59] explains, most of the cycling superhighways implemented by Germany are well suited for urban areas. As a result, this has motivated many people, especially women, to cycle even when going to work. In this case, it is not surprising that the government of Germany is providing an annual €25 million dedicated for improving cycling superhighways.

4.3. Case of Uganda

In Uganda, cycling among women is not common. In fact, bicycles are commonly used in rural areas where young men use them for transporting commodities, especially cash crops to the markets. More so, bicycles are intensively used in Northern and Eastern Uganda compared to Western and Central areas. According to New Vision [60], very few women cycle in Uganda, and this is attributed to the terrain and cultural beliefs regarding women in most parts of the country. For example, in some cultures (rural areas) in Uganda, some people still believe that women are not supposed to cycle. The reason is that their culture prohibits them from sitting with their legs apart.

Much as Uganda needs more women to cycle, most urban centers including Kampala are not the best places to use bicycles (Figure 3). One of the reasons is that most of these urban centers are congested, and they do not have facilities or better infrastructure to support cycling, and this limits the city from achieving sustainable transport and smart city options (Figure 3). Nonetheless, New Vision [60] reported Amanda explaining that using bicycles is more economical compared to cars. Besides, it is also environment-friendly. For short distances, Amanda explained that bicycles are better mode of transport despite the challenges in Uganda.



Figure 3. Cycling in Uganda (Photo credit: Amanda Ngabirano).

Despite their cultural background, women in central Uganda, especially Kampala, Wakiso and Entebbe, cycle but at a lower level [60]. For example, New Vision [60] reported that one of the female lecturers at Makerere University has inspired most women to cycle in one way or another. According to the reports, Amanda Ngabirano is a passionate advocate of the use of bicycles as one of the modes of transport in Uganda, especially in the Capital Kampala, where traffic is intense. In an article by PML Daily [61], Ngabirano believes that women who cycle are despised in most cultures. However, Amanda is optimistic that such culture should change, and the government of Uganda needs to invest in safe infrastructure that can encourage many women to cycle.

4.4. Case of Kenya

Just like in most of the developing countries, a reliable means of transport is considered to be one of the core factors in economic development in Kenya. According to Alando and Scheiner [62] cycling in most cities in African countries including Kenya faces unending exclusion, especially from the street spaces. Much as cycling is one of the cheapest transport means in East African countries, there is still limited infrastructure that supports cycling in the country. Besides general challenges, women in Kenya still experience exclusion when it comes to the transport sector [62]. In fact, few women cycle as many are limited by cultural beliefs that women are not supposed to ride bicycles. In this case, therefore, it is worth mentioning that these cultural beliefs continue to limit cities like Nairobi and other developing countries when it comes to achieving sustainable transport and smart city status.

However, Kibet [63] explained that Kenyan women and girls are getting involved in cycling like never before. For example, the author indicated that various schools in Kenya are receiving bicycle donations targeting girls who walk long distances while going to school. More so, girls who benefit from these donations are very happy, and they cycle every day to and from school. Kibet [63] indicates that the World Bicycle Relief that is working with the Ministry of Education in Kenya provided more than 3000 bicycles to various schools in Kenya in 2016. These bicycles are targeting girls who walk long distances to school, and this is changing the culture of cycling in the country. According to recent research, the Kenyan government is addressing most of the problems that limit the level of cycling [62]. For example, the Kenyan vision of 2030 focuses on integrating inclusion policies into national transport framework. Such policies are aimed at supporting men and women who want to cycle to have an opportunity. In this case, therefore, it is worth mentioning that women are still few when it comes to cycling in Kenya, and this is due to most of the challenges that have been mentioned.

5. Discussion and Conclusions

Based on a wide range of literature reviewed, it is worth mentioning that sustainable transportation remains one of the core drivers for socio-economic and environmental development across the globe. More so, various definitions have been explored in a bid to understand all aspects that rotates around sustainable transport in smart cities. For example, one of the definitions of sustainable transport capture three core values, which are basic for most people to understand. First, such a system would be permitting of safe and consistent access to individual and societal basic needs, while securing both human and ecosystem health to ensure stability for future generations. Second, sustainable transport must have value for money through efficiency in operation and affordability, while offering various alternative transport modes to choose from. Thirdly, it should be environmentally friendly in terms of GHG emissions among other variables.

In all three core values, it was revealed that sustainable transport focuses on the ability of societies to make development sustainable while ensuring that it meets the needs of the present without compromising those of future generations. On the same note, it was noted that any unsustainable forms of transport are those that directly cause harm to the environment, in both short- and long-term estimations. In other words, sustainable transportation is a primary concept that actuates social and economic development. Thus, various studies concluded that sustainable transport clearly is the answer to the rather lacking present transportation entities in the world, and this suggests strong opportunities for its wholesome adoption in the future.

When it comes to smart cities, it was highlighted that the ever progressive infrastructure developments must be sustainable as well. More studies indicated that smart cities require flexible transportation systems such as cycling. However, this investigation revealed that smart solutions for smart cities requires safe infrastructure and integration of technology to allow travelers to get more connected while monitoring their movements. Sustainable transport is one aspect of smart cities and contributes to numerous other components that make up a smart city. Both sustainable transport and smart cities' main goal aims at facilitating a better life for the communities in the cities especially with

reducing carbon emissions, and when it comes to bicycles, they are ranked cutting edge, and the same goes for the food-print of excess energy used when cycling.

In this paper, we concentrated on understanding the major concept of 'sustainable transport and smart cities'. However, we zeroed on one aspect which is cycling and the role women play herein, with many examples and cases given from given countries (Figure 1).

Cycling is a common form of smart transportation commonly practiced in modern cities. In many countries, public bicycle systems under local governments or non-governmental organizations have been set up to share bicycles amongst inhabitants to allow traffic flow. A wide range of examples of smart cities were cited, as well as the mode of transport such cities are using. For example, it was found out that most of the modern Western cities have gone the extra mile to establish smart transport systems to enhance the flow of urban traffic better while improving the mobility of their inhabitants. On the same note, it was indicated that it has become a trend for many modern cities to transition into the digital age through the purposeful integration of information and improved infrastructure.

However, most of the transport systems being implemented by various cities still face several bottlenecks. For example, much as cycling system is doing well in most of the Western countries such as the Netherlands, the majority of developing countries face many challenges. To rigorously support cycling, there is a need for infrastructure development such as building cycling lanes and bridges to accommodate this smart transportation, funding which might not come cheap for many cities. Nonetheless, smart transportation offers flexibility and greener transportation alternatives for a multiplicity of modern cities, and is thus a great necessity. More so, it is beyond doubt that most of the urban plans for sustainable and smart cities largely center on cars as the primary form of transportation. Nonetheless, it is imperative for any given modern city venturing into cycling to invest a considerable amount of effort while focusing on establishing necessary infrastructure that is secured and at the same time sustainable.

For women in transport, it was indicated that women play a critical role in current transport infrastructure. In most cases, women are always concerned with the safety and personal security elements of transport. More so, several studies [35,51,57] indicated that better transportation systems have always contributed to people's quality of life in a given society. In this case, allowing women to participate in policymaking, especially on sustainable transport, has brought economic growth and efficient transport systems in most cities. Further studies revealed that despite the improvements in travel patterns and the role of women in sustainable transport, their contribution is still less compared to men. For example, women still tend to have shorter commutes, especially in terms of time traveled and distance. As a result, this continues to limit their influence over policies that can favor them one way or another.

With the aim of getting to the core of the concept, various cases have been explored. Some of these cases represent Western countries and other African or developing countries. Western countries where they have achieved a high level of sustainable transport in smart cities include the Netherlands and Germany. On the other hand, Uganda and Kenya cases represented developing countries, especially on the aspect of women in cycling as mode of transport in smart cities. Based on various cases of women cycling, it is worth mentioning that the Netherlands continue to lead Germany, Kenya, and Uganda. More so, research indicates that cyclists in the Netherlands and Germany [57] have better infrastructure when it comes to cycling as compared to East African countries (Uganda and Kenya).

Compared to Germany and the Netherlands, Uganda and Kenya have different backgrounds in terms of bicycle transport. We observed that it is very normal and healthy for both women, men and children to ride for health, environment and transportation in the former, while in Uganda and Kenya, women are not accepted as far as riding bicycles is concerned. In some cultures, it is even completely prohibited. In general, most African families do not allow the girls to even learn how to ride. It is in the most recent times that actually women can comfortably ride bicycles in Africa, and yet they still face a lot of societal unacceptance, and are sometimes laughed at or even abused if not punished. Additionally, its considered transport for poor people in most African societies.

Nonetheless, this research revealed that cycling is not the only element that can help cities to develop sustainable transport systems. In fact, it was indicated that cities need to build strong partnerships with various actors in a bid to enable the smart city level. Based on this investigation, sustainable transport for smart cities require research and innovation in both big and small cities. In this case, smart cities should aim at engaging all citizens with better policies, and by bringing together hard infrastructure, local skills, social capital and technology to mention but a few. It is through setting up safe infrastructure, the integration of technology and women inclusiveness in the transport sector that Kampala, the capital city of Uganda, can start the journey of becoming a smart city, and the setting goes for other aspiring cities.

For cities like Nairobi, Kenya to become one of the smart cities in the world, the current transport sector should be reshaped to experience a paradigm shift. In one way or the other, this paradigm shift should focus on achieving smart city objectives including the integration of technology in transport systems, public bicycles and bike-sharing to mention but a few. Nairobi, the capital city of Kenya, can achieve smart city status by ensuring that travelers including women in the city are more connected. In other words, all public transport users such as cyclists and those using vehicles and other means can use technology to monitor their movement. Various benefits including traffic flow and other health advantages for both men and women can be achieved.

For example, with its high cycling mode share, there is no doubt that the Netherlands has better policies and motivations that encourage people to cycle on frequently. In fact, research indicates that women in the Netherlands cycle more than men. As indicated in the above case studies, there is a significant difference between the Netherlands, Germany, Kenya, and Uganda as far as women in cycling transport is concerned. For example, the Netherlands and Germany have made it easier for women and men to cycle by providing advanced infrastructure that favors cycling. In Uganda and Kenya, cultural differences continue to limit women from cycling, and there is still poor infrastructure for safe cycling. Despite the challenges, sustainable transport clearly is the answer to the rather lacking present transportation entities in the world, thus suggesting strong opportunities for its wholesome adoption in the future.

Much as the study provides a comprehensive analysis of sustainable transport for smart cities, there is a wide range of drawbacks that limited this investigation. One of the limitations is that the scope of the study is limited to a few cases, especially Germany, the Netherlands, Kenya, and Uganda. Notwithstanding the fact that sustainable transport for smart cities presents complex aspects regarding economic development, this study focused much on cycling. Nonetheless, this study addressed the existing gap in literature regarding sustainable transport for smart cities. However, more research with wider case studies and primary information should be carried out to shed more light on this subject.

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References

1. Transport Must Answer Needs of ‘Those Who Have the Least’, Says Secretary-General as Global Conference Opens in Turkmenistan. Available online: <https://www.un.org/press/en/2016/envdev1758.doc.htm> (accessed on 10 November 2018).
2. Köhler, J. Globalization and Sustainable Development: Case Study on International Transport and Sustainable Development. *J. Environ. Develop.* **2013**, *23*, 66–100. [[CrossRef](#)]

3. Rassafi, A.A.; Vaziri, M. Sustainable transport indicators: Definition and integration. *Int. J. Environ. Sci. Technol.* **2005**, *2*, 83–96. [[CrossRef](#)]
4. Hall, R.P. Introducing the Concept of Sustainable Transportation to the U.S. DOT through the Reauthorization of TEA-21. Master's Thesis, Massachusetts Institute of Technology, Cambridge, MA, USA, June 2002.
5. Hall, R.P. Understanding and Applying the Concept of Sustainable Development to Transportation Planning and Decision-Making in the US. Ph.D. Thesis, Massachusetts Institute of Technology, Cambridge, MA, USA, 2006.
6. Kronsell, A.; Smidfelt Rosqvist, L.; Winslott Hiselius, L. Achieving climate objectives in transport policy by including women and challenging gender norms: The Swedish case. *Int. J. Sustain. Transp.* **2015**, *10*, 703–711. [[CrossRef](#)]
7. Litman, T.; Burwell, D. Issues in sustainable transportation. *Int. J. Glob. Environ. Issues* **2006**, *6*, 331–347. [[CrossRef](#)]
8. Malasek, J. A Set of Tools for Making Urban Transport More Sustainable. *Transp. Res. Procedia* **2016**, *14*, 876–885. [[CrossRef](#)]
9. Zhou, J. Sustainable transportation in the US: A review of proposals, policies, and programs since 2000. *Front. Archit. Res.* **2012**, *1*, 150–165. [[CrossRef](#)]
10. Black, W.R. *Sustainable Transport: Definitions and Responses. Integrating Sustainability into the Transportation Planning Process*; National Academics Press: Washington, DC, USA, 2004; pp. 35–43.
11. Scholl, L.; Schipper, L.; Kiang, N. CO₂ emissions from passenger transport. A comparison of international trends from 1973 to 1992. *Energy Policy* **1996**, *24*, 17–30. [[CrossRef](#)]
12. Friedl, B.; Steininger, K. Environmentally Sustainable Transport: Definition and Long-Term Economic Impacts for Austria. *Empirica* **2002**, *29*, 163–180. [[CrossRef](#)]
13. Legacy, C.; Curtis, C.; Scheurer, J. Planning transport infrastructure: Examining the politics of transport planning in Melbourne, Sydney and Perth. *Urban Policy Res.* **2017**, *35*, 44–60. [[CrossRef](#)]
14. Black, W.R. Sustainable Transport and Potential Mobility. *Eur. J. Transp. Infrastruct. Res.* **2002**, *4*, 176–196. [[CrossRef](#)]
15. Nachmias, D.; Nachmias, C. Content analysis. *Res. methods Soc. Sci.* **1976**, *0*, 132–139.
16. Elo, S.; Kyngas, H. The qualitative content analysis process. *J. Adv. Nurs.* **2008**, *62*, 107–115. [[CrossRef](#)]
17. Creswell, J.W. *Educational Research: Planning, Conducting and evaluating Quantitative and Qualitative Research*, 4th ed.; Pearson education, Inc: Boston, MA, USA, 2012.
18. Dia, H. Intelligent Mobility for Smart Cities. Available online: http://www.roads.org.au/Portals/3/CONFERENCE/Hussein_Dia.pdf (accessed on 22 October 2018).
19. Hirst, P.; Hummerstone, E.; Webb, S.; Karlsson, A.K.; Blin, A.S.; Duff, M.; Jordanou, M.; Deakin, M. JESSICA for Smart and Sustainable Cities—Final Report. Available online: https://ec.europa.eu/regional_policy/sources/thefunds/instruments/doc/jessica/jessica_horizontal_study_smart_and_sustainable_cities_en.pdf (accessed on 22 October 2018).
20. Olaverri, C. Intelligent technologies for mobility in Smart Cities. Available online: https://www.hte.hu/documents/10180/1727937/HT_2016-1_MJIK2015_4_Olaverri-Monreal.pdf (accessed on 12 November 2018).
21. United Nations Commission on Science and Technology for Development. Issues Paper on Smart Cities and Infrastructure. Inter-sessional Panel 2015–2016, United Nations Commission on Science and Technology for Development. Available online: https://unctad.org/meetings/en/SessionalDocuments/CSTD_2015_Issuespaper_Theme1_SmartCitiesandInfra_en.pdf (accessed on 12 November 2018).
22. Sugimoto, C.; Nakamura, Y.; Hashimoto, T. Prototype of pedestrian-to-vehicle communication system for the prevention of pedestrian accidents using both 3G wireless and WLAN communication. In Proceedings of the 3rd International Symposium on Wireless Pervasive Computing, Santorini, Greece, 7–9 May 2008. [[CrossRef](#)]
23. Banks, I. Future of Mobility: Smart Transport Infrastructure. Available online: <https://circulatenews.org/2016/06/future-of-mobility-smart-transport-infrastructure/> (accessed on 22 October 2018).
24. Mitra, R.; Nash, S. Can the built environment explain gender gap in cycling? An exploration of university students' travel behavior in Toronto, Canada. *Int. J. Sustain. Transp.* **2018**, *2*, 1–10. [[CrossRef](#)]
25. CIVITAS. Intelligent Transport Systems and Traffic Management in Urban Areas. Available online: http://www.eltis.org/sites/default/files/trainingmaterials/civ_pol-not6_its_web.pdf (accessed on 22 October 2018).

26. Benevolo, C.; Dameri, R.; D'Auria, B. Smart Mobility in Smart City. In *Empowering Organizations—Enabling Platforms and Artefacts*; Torre, T., Barccini, A.M., Spinelli, R., Eds.; Springer International Publishing: Cham, Switzerland, 2016; Volume 11, pp. 13–28.
27. European Economic and Social Committee. The White Paper on Transport. Available online: <https://www.eesc.europa.eu/> (accessed on 22 October 2018).
28. Giffinger, R.; Fertner, C.; Kramar, H.; Kalasek, R.; Pichler-Milanovic, N.; Meijers, E. Smart Cities—Ranking of European medium-sized cities. Vienna University of Technology. Available online: http://www.smart-cities.eu/download/smart_cities_final_report.pdf. (accessed on 22 October 2018).
29. Dameri, R.P. ICT Intensity in Smart Mobility Initiatives. In *Smart City Implementation*; Springer International Publishing: Cham, Switzerland, 2017; pp. 85–108.
30. Haixiao, P. Chapter 7 Evolution of Urban Bicycle Transport Policy in China. In *Cycling and Sustainability (Transport and Sustainability, Volume 1)*; Emerald Group Publishing Limited: Bingley, UK, 2012; pp. 161–180.
31. Aldred, R.; Jungnickel, K. Why culture matters for transport policy: the case of cycling in the UK. *J. Transp. Geogr.* **2014**, *34*, 78–87. [[CrossRef](#)]
32. Poppe, S. Cycling as a Serious Mode of Transport—Traditional, Innovative, Sustainable. Available online: <http://www.eurocities.eu> (accessed on 16 November 2018).
33. Larsen, J. Bike-Sharing Programs Hit the Streets in Over 500 Cities Worldwide. Available online: http://www.earth-policy.org/plan_b_updates/2013/update112 (accessed on 11 November 2018).
34. Todhunter, C. Cycling Smart in Copenhagen: Smart Cities Call For Smart Solutions. Available online: <https://www.counterpunch.org/2016/01/12/cycling-smart-in-copenhagen-smart-cities-call-for-smart-solutions/> (accessed on 10 November 2018).
35. Madsen, A.K. Data in the smart city: How incongruent frames challenge the transition from ideal to practice. *Big Data Soc.* **2018**, *5*, 1–13. [[CrossRef](#)]
36. Behrendt, F. Why cycling matters for Smart Cities. Internet of Bicycles for Intelligent Transport. *J. Transp. Geogr.* **2016**, *56*, 157–164. [[CrossRef](#)]
37. Lanza, I.D. Cyclists and Walkers Lead Mexico City on the Road to Sustainability. Available online: <https://thecityfix.com/blog/cyclists-walkers-lead-mexico-city-road-sustainability-ivan-de-la-lanza/> (accessed on 10 November 2018).
38. Gasiorowski, E. Smart cities get on their bikes. Available online: <https://www.iso.org/news/2015/09/Ref1998.html> (accessed on 22 October 2018).
39. Graham, G.G.; Zhang, L. Smart cities and digital technologies: the case of bike sharing. EurOMA sustainable operations and supply chain forum. Available online: www.euroma-online.org (accessed on 22 October 2018).
40. Zhang, L.; Zhang, J.; Duan, Z.; Bryde, D. Sustainable bike-sharing systems: characteristics and commonalities across cases in urban China. *J. Clean. Prod.* **2015**, *97*, 124–133. [[CrossRef](#)]
41. Marqués, R.; Hernández-Herrador, V.; Calvo-Salazar, M.; García-Cebrián, J. How infrastructure can promote cycling in cities: Lessons from Seville. *Res. Transp. Econ.* **2015**, *53*, 31–44. [[CrossRef](#)]
42. Pinna, F.; Masala, F.; Garau, C. Urban Policies and Mobility Trends in Italian Smart Cities. *Sustainability* **2017**, *9*, 494. [[CrossRef](#)]
43. Garrard, J.; Rose, G.; Lo, S.K. Promoting transportation cycling for women: The role of bicycle infrastructure. *Prev. Med.* **2008**, *46*, 55–59. [[CrossRef](#)]
44. Garrard, J. Healthy revolutions: promoting cycling among women. *Health Promot. J. Aust.* **2003**, *14*, 213–215. [[CrossRef](#)]
45. Garrard, J.; Crawford, S.; Hakman, N. *Revolutions for Women. Increasing Women'S Participation in Cycling for Recreation and Transport*; Deakin University: Geelong, Australia, 2006.
46. Sarkar, A.; Lathia, N.; Mascolo, C. Comparing cities' cycling patterns using online shared bicycle maps. *Transportation* **2015**, *42*, 541–559. [[CrossRef](#)]
47. Grudgings, N.; Hagen-Zanker, A.; Hughes, S.; Gatersleben, B.; Woodall, M.; Bryans, W. Why don't more women cycle? An analysis of female and male commuter cycling mode-share in England and Wales. *J. Transp. Health* **2018**, *10*, 272–283. [[CrossRef](#)]
48. Teschke, K.; Chinn, A.; Brauer, M. Proximity to four bikeway types and neighborhood-level cycling mode share of male and female commuters. *J. Transp. Land Use* **2017**, *10*, 695–713. [[CrossRef](#)]
49. Singh, S.K. Scenario of urban transport in Indian cities: challenges and the way forward. In *Cities and Sustainability*; Springer: New Delhi, India, 2015; pp. 81–111.

50. Kunieda, M.; Gauthier, A. Gender and Urban Transport: Smart and Affordable. Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities. Available online: <https://www.itdp.org/wp-content/uploads/2014/07/7aGenderUTSept300.pdf> (accessed on 10 November 2018).
51. Root, A.; Schintler, L.; Button, K. Women, travel and the idea of 'sustainable transport'. *Transp. Rev.* **2010**, *20*, 369–383. [[CrossRef](#)]
52. Buckingham, S. Keynote Speech: The Advantages of Involving Women in Sustainable Development Planning. Energy, Environment and Sustainable Development. In *Energy, Environment and Sustainable Development*; Uqaili, M.A., Harijan, K., Eds.; Springer: Vienna, Austria, 2012.
53. Aljounaidi, L. Gender and Transport in MENA: Case Studies from West Bank Gaza and Yemen. Available online: <https://openknowledge.worldbank.org/bitstream/handle/10986/10935/533780BRI0MNA010Box345607B01PUBLIC1.pdf?sequence=1&isAllowed=y> (accessed on 22 October 2018).
54. AFCAP. Scaling up Gender Mainstreaming in Rural Transport: Ghana Case Study Report. Analysis of Policies, Practices, Impacts and Monitoring Processes. 2017. Available online: <https://assets.publishing.service.gov.uk/media/5ac47f3240f0b60a4be86d44/AmoakoSakyi-IFRTD-2017-ScalingUpGMAAnalysisPoliciesPractiesImpactsMonitoringProcesses-GhanaCS-AfCAP-RAF2044J-171208-redacted.pdf> (accessed on 22 October 2018).
55. Pucher, J.; Buehler, R. At the Frontiers of Cycling. Policy Innovations in The Netherlands, Denmark, and Germany. *World Transp. Pract.* **2007**, *13*, 8–57.
56. Pucher, J.; Buehler, R. Making Cycling Irresistible: Lessons from The Netherlands, Denmark and Germany. *Transp. Rev.* **2008**, *28*, 495–528. [[CrossRef](#)]
57. Harms, L.; Bertolini, L.; Brömmelstroet, M.T. Performance of municipal cycling policies in medium-sized cities in the Netherlands since 2000. *Transp. Rev.* **2016**, *36*, 1–29. [[CrossRef](#)]
58. BBC Magazine. Why Do so Many Dutch People Cycle? Available online: <https://www.bbc.com/news/magazine-23587916> (accessed on 22 October 2018).
59. BMVI. Cycling in Germany is booming. Available online: <https://www.bmvi.de/SharedDocs/EN/Dossier/Cycling/cycling-in-germany-is-booming.html> (accessed on 22 October 2018).
60. New Vision Reporter. Amanda Ngabirano: the Ugandan who Inspired Swedish filmmakers. Available online: https://www.newvision.co.ug/new_vision/news/1431631/amanda-ngabirano-ugandan-inspired-swedish-filmmakers (accessed on 15 November 2018).
61. PML Daily. Amanda Ngabirano: Nothing will stop Makerere Don from Cycling to Class. Available online: <http://www.pmldaily.com/features/2017/06/amanda-ngabirano-nothing-will-stop-makereres-feisty-cycling-lecturer.html> (accessed on 16 November 2018).
62. Alando, W.; Scheiner, J. Framing Social Inclusion as a Benchmark for Cycling-Inclusive Transport Policy in Kisumu, Kenya. *Soc. Incl.* **2016**, *4*, 46–60. [[CrossRef](#)]
63. Kibet, R. Kenyan Girls Get on Their Bikes in Pursuit of an Education. Available online: <https://www.theguardian.com/global-development/2016/jun/24/kenyan-girls-bikes-pursuit-of-education> (accessed on 10 November 2018).



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