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Review

Carbon Footprints of Active and Non-Active Transport Modes: Hierarchy and Intergenerational Narrative Analyses

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Abstract: This paper aimed to (1) develop a hierarchy for understanding the impacts of active and non-active transport modes on the environment and (2) analyse the adoption of active transportation between older and younger people. A narrative review with two parts was adopted to develop the hierarchy. In the first part, a framework was adopted to map active and non-active transport modes onto three operational boundaries of greenhouse gas emission to develop the hierarchy. In the second part, an intergenerational theoretical framework was developed to analyse the adoption of active transportation between older and younger people. The review suggests that the only active transport modes with no or negligible carbon footprint are walking, running, and swimming without a product that adds to atmospheric greenhouse gases. The evidence that younger people perform higher active transportation behaviour is inconsistent and is, therefore, inconclusive. This review suggests a need for manufacturers to prioritise the production of active vehicles (e.g., wheelchairs and scooters) that are biodegradable, recyclable, and small.

Keywords: carbon footprint; active transportation; older adults; generations; health

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1. Introduction

Research assessing carbon dioxide equivalent emissions often called a carbon footprint [1] has gained momentum in recent years in response to an increase in global greenhouse gas emissions from individuals [1,2]. A parallel development is the acceleration of research on the health-sustainability dimension of transportation, with an emphasis on avoiding or decreasing per capita carbon footprint through active transportation, defined as walking or cycling to a place [3]. This definition undermines other forms of active transportation, resulting in active transportation being operationally defined as moving to places in ways involving physical activity but not involving the combustion of fossil fuels. This definition was informed by the above health-sustainability research agenda that emphasises the role of active transportation in health and environmental protection [1,2]. This agenda ought to progress since one-fifth of greenhouse gas emissions come from transportation involving the combustion of fossil fuels alone [1,2].

Walking, for example, may involve a negligible emission of greenhouse gases each time it is performed. In this review, any such travel behaviour is treated as an active transport mode with a zero-carbon footprint. The term "transport mode" has been used in the literature [4] to refer to different ways to travel between places (e.g., walking, bicycling, and driving). In this paper, therefore, we use this phrase to refer to various ways to travel.

The literature to date suggests that walking may be the ultimate physical activity for older adults because it requires less physical strength and energy expenditure [5,6]. As such, it can be sustained over the life course by all age groups, an idea that recalls a recent debate in gerontology about the role of older adults in environmental activism [7,8]. This debate has portrayed older adults as victims of ageism championed by younger adults who are concerned about climate change and the future [9]. Younger generations are concerned that older adults are responsible for climate change since older adults generally lead environmental policy interventions that have been unproductive [7,8]. An aspect of the literature also suggests that older adults have had more time to contribute to the emission of greenhouse gases and are less interested in pro-environmental behaviours, such as active transportation [9]. These ageist views imply older adults contribute less to environmental sustainability through active transportation.

Ageist views about older adults threaten the solidarity needed between older and younger generations to fight climate change [7–9]. Pro-environment behaviours (e.g., walking) are potentially the best ways to reduce carbon footprint and achieve sustainability goals [10,11], but their positive influence on the environment depends on how many people practice them. When ageist views are prevalent in climate crises and sustainability discussions, initiatives become divisive and undermine the significant role older adults can play in overcoming the climate crisis. This is particularly important, especially in a world where the population is rapidly ageing [12] and sustainability initiatives include many older adults.

Given the above concerns, the authors aimed to develop a heuristic for understanding the carbon footprints of active and non-active transport modes. This heuristic is needed because, though studies suggest active modes of transportation are the best ways to minimise per capita emission of greenhouse gases [10,11], there is no framework describing their respective carbon footprints. The authors further analysed the adoption of active transportation between older and younger people through a theoretical framework delineating active transportation behaviour across four generations (i.e., children, adolescents, adults, and older adults).

This review is significant for some reasons. Though studies have reported active and non-active transport modes with their potential carbon footprints, this review is the first to put these forms of transportation on a hierarchy, enabling stakeholders to better appraise the role active transportation plays in campaigns for a safer environment. The hierarchy may serve as a model for empirically investigating the relative impacts of transport modes on the environment. It is generally assumed that active modes of transportation protect the environment, but this review suggests otherwise. With this review, individuals may consider ways to use active vehicles (e.g., bicycles, scooters, and wheelchairs) without generating a carbon footprint. The hierarchy can encourage manufacturers to consider opportunities for designing vehicles to make them more active. Our intergenerational analysis may correct the assumption that the adoption of active transport modes is not necessarily higher among younger people. This contribution of the review is a way to better value the role of older adults in pro-environment campaigns, encourage stakeholders to include older adults in such campaigns, and ensure that as many older adults as possible are included in campaigns encouraging active transportation adoption, given that there may be more older people than younger ones in the world in the coming decades.

2. Search Methodology in Brief

A narrative review was adopted, and the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guideline was followed to search and review the literature. The search aimed to identify up-to-date documents reporting active or non-active transportation concerning greenhouse gas emissions and its personal as well as psychosocial predictors. Appendix A is the review work plan showing the inclusion and exclusion criteria, search terms, and SPIDER (Sample, Phenomenon of Interest, Design, Evaluation, Research type) tool used. Appendix B is the PRISMA flowchart reached using the inclusion and exclusion criteria to select suitable documents. The databases searched were PubMed, ProQuest, PsychInfo, CINAHL, Google Scholar, and Scopus. MeSH (Medical Subject Headings) terms were identified and developed into a search string using PubMed. These databases were searched twice as shown in Appendix A.

The steps taken in the review were (1) systematic searches; (2) screening of titles and abstracts of 5% of the studies twice to pilot the inclusion criteria; (3) screening of full texts by one of the authors; and (4) checking of data extraction for 20% of studies. Two researchers independently piloted abstract and title screening on 5% of the records downloaded. Inconsistencies in the pilot results were discussed and resolved before proceeding to the next stage. The titles and abstracts of the remaining 95% of the records were screened by the individual researchers. Subsequently, the full texts of the records selected through title and abstract screening were assessed for inclusion in the review against the inclusion criteria. The lists of references of included studies were examined to select relevant articles that had not been downloaded into the bank of records realised from our screening of titles and abstracts. Appendix B is the PRISMA flowchart resulting from the review. To ensure that quality documents were reviewed, we focused on peer-reviewed journals indexed in Web of Science, Scopus, or PubMed.

Only 26 documents were deemed appropriate for this review (see Appendix B), though other complementary documents outside the scope of the search were used. Data were extracted independently by one author and a research assistant with a piloted data extraction Excel sheet. The author and research assistant discussed in person to resolve minor disagreements in data extraction. Seven of the studies [13–19] reported active transport modes, namely, walking, running (i.e., jogging), swimming, bicycling, skating (including skateboarding and roller skating), skiing, surfing, scooter or wheelchair use (including kick scooter use), and rowing. Non-active transport modes dependent on fossil fuels include motorcycling, driving a car, ship travel, train travel, and air travel. A study [1] reported a framework that could be used to assess the carbon footprint of transport modes. Some studies [19–29] also assessed the relationship between age, pro-environment behaviour, and active transportation adoption.

3. A Framework for Assessing Carbon Footprint

This review focused on the carbon footprint of individuals and how this can be reduced or avoided through active transportation. To meet this aim, a carbon footprint is defined as the exclusive total amount of carbon dioxide emissions that are directly or indirectly caused by an activity or accumulated over the lifespan of a product [1]. This definition suggests that a carbon footprint can be generated directly or indirectly by an individual through daily behaviours. A direct example is driving a petrol- or diesel-dependent car, which directly releases greenhouse gases into the atmosphere. Indirect examples are producing non-biodegradable waste through the consumption of products (e.g., a canned drink) or felling down trees to provide services or products. Non-biodegradable waste produces greenhouse gases [30], whereas the felling of trees would increase the concentration of greenhouse gases in the atmosphere by reducing the proportion of trees absorbing these gases while releasing oxygen.

The foregoing definition makes Wicker's framework [1] for assessing carbon footprint ideal for the current review. It comprises three operational boundaries or scopes that specify whether some behaviours generate a carbon footprint. These behaviours are within three scopes. Scope 1 comprises direct emissions resulting from onsite fuel consumption, including all emissions from combustions relating to the use of vehicles. This includes behaviours causing emissions from travelling to a destination, with a typical example being driving a car. Scope 2 encompasses direct emissions from purchased electricity, heating, and cooling. This category includes heating or cooling a vehicle while travelling and wearing, for example, an electric jacket to keep warm while walking during the winter. Scope 3 concerns indirect emissions occurring during the lifespan of a product, including emissions resulting from the production and distribution of a product and management of waste.

Indirect emissions relate to the production of products requiring a supply chain dependent on the transportation of goods and individuals.

To use the above framework [1], the authors decided whether individual transport behaviours can directly or indirectly produce any greenhouse gas per unit of time. Each transport behaviour was mapped onto all three operational scopes with a "yes" (i.e., scope applicable) or "no" (i.e., scope not applicable) decision, which allowed us to determine whether the behaviour generates a carbon footprint directly or indirectly. To achieve reliable results, two researchers with expertise in transportation research performed independent mappings, which produced consistent findings. A zero-carbon footprint was achieved if a transport behaviour, hereby referred to as absolute active transportation, did not result in a greenhouse gas emission across the three scopes. Any active transport behaviour that was associated with emission for at least one scope had a carbon footprint and could be referred to as partial active transportation.

Whether an individual would use or adopt an active transport mode depends on several factors, such as the social and physical environment, as well as age [27,31]. In view of these factors, the adoption of active transportation between older and younger people is analysed through a theoretical framework explaining unique opportunities and barriers to active transportation across four generations. Children between 0 and 12 years who cannot make transport decisions for themselves are the first generation, whereas teenagers and adolescents aged 13–17 years who can make transport decisions but are dependent on parents are the second generation. Adults aged 18–49 years who can make transport decisions and may be independent of their parents are the third generation. The minimum for what is considered old age differs between countries; the United Kingdom (UK), for instance, sets the minimum old age at 65 years [32], whereas Ghana sets it at 60 years [33]. Globally, the minimum old age is 50 years [32,34]. Although the minimum age of 50 is not a good indicator of the individual's health and physiological conditions [34], it is a globally acceptable baseline. Thus, older people are operationally defined as individuals aged 50 years or higher and are the fourth generation.

4. Carbon Footprint and a Hierarchy of Active Transport Modes

The hierarchy of active transport modes is the pyramidal heuristic showing the relative impacts of transport modes on the environment. This framework was developed by mapping identified transport modes onto the operational scopes, which are recalled and operationalised as follows:

Scope 1—direct emissions resulting from onsite fuel consumption, including all emissions from combustions relating to the use of vehicles.

With this scope, any transport behaviour not involving the combustion of fossil fuel and not emitting a greenhouse gas does not generate a carbon footprint. As such, any transport behaviour that involves the combustion of fossil fuel applies to this scope and is mapped onto it with "yes" (with red colour).

Scope 2—direct emissions from purchased electricity, heating, and cooling. These emissions come from the use of air-conditioning systems that may be part of vehicles.

This scope does not require the direct combustion of fossil fuel in transportation but involves heating or cooling through air conditioning, which results in the emission of greenhouse gases [35]. Individuals with pro-environment behaviours may decide to drive an electric car, but they may use heating or cooling systems in the car (e.g., an air-conditioner) which produce greenhouse gases. Someone walking during the winter may wear a jacket with an inbuilt or mobile heating system, which may generate a carbon footprint. Therefore, any transport behaviour that uses a heating or cooling system and could emit greenhouse gases applies to this scope and is mapped onto it with "yes".

Scope 3—emissions that occur during the lifespan of a product, including those from the production and distribution of a product and management of waste from this product.

Any product whose production indirectly increases the concentration of greenhouse gases in the atmosphere is considered environmentally unfriendly. For instance, the production of products dependent on wood requires the felling of trees that absorb some greenhouse gases, such as carbon dioxide. From this perspective, the use of biodegradable products (e.g., a bicycle made of wood) indirectly generates a carbon footprint. Secondly, the use of any product that can become a part of waste in its production or consumption indirectly generates a carbon footprint. This assumption is premised on research [30] indicating that waste is a major source of greenhouse gases, such as methane. The quantity of greenhouse gases emitted partly depends on the size of a product; larger products that are not biodegradable or cannot be recycled would add more waste to the environment and may, therefore, generate a higher carbon footprint. Biodegradable waste, compared to non-biodegradable waste (e.g., plastics), has a shorter lifespan, so its carbon footprint can be expected to be short-lived. Similarly, recyclable waste would generate a smaller footprint.

Table 1 shows the results of mapping all transport modes onto the three operational scopes. Mapping was based on whether the transport behaviour involves the use of a product that could be harmful to the environment, depends on a utility or energy source that emits greenhouse gases, and whether the product is small, biodegradable, or recyclable. It was also assumed that greenhouse gas emissions across the lifespan of fuel-dependent transport modes (i.e., motorcycle, car, ship, train, and aeroplane) are more than emissions across the lifespan of active transport modes. Only walking, running, and swimming with no or negligible greenhouse gas emissions constitute absolute active transportation. "Walking (PS)" in the table may be associated with a significant emission of greenhouse gases and may, thus, has a carbon footprint. A study [1] has revealed that individuals may drive to convenient destinations before performing sporting activities or active transportation behaviours. Such individuals directly generate a carbon footprint before performing an active transportation behaviour at the chosen destination. Others might use canned energy drinks and other products during active transportation (e.g., walking) which may add up to waste, especially if not properly disposed of. The use of products, especially non-biodegradable ones, in active transportation can have a significant detrimental impact on the environment in the long term.

Figure 1 (based on Table 1) depicts the heuristic of walking as the most environment-friendly active transportation behaviour. The non-active transport modes are at the base of the framework, which signifies that transportation involving the combustion of fossil fuels has the highest carbon footprint. Walking is above running on the pyramid for two reasons. Firstly, research has suggested that walking, compared to running, is more sustainable across the lifespan because it requires less energy expenditure and is part of daily routines [5]. This being so, more people can be expected to perform walking behaviours and impact the environment positively. Secondly, whether people would sustain walking or running as a behaviour depends on their connectedness to nature [36], hereby defined as the amount of time spent observing lawns, forests, gardens, wildlife, rivers, and other natural attributes of the physical environment. People who walk may be better engaged with nature because they can more closely observe and admire nature. In running, people hurriedly observe nature, so their nature-driven motivation to keep fit through running would be low, compared with people who walk. Swimming is set below running in the framework because it is less relaxing and, if conducted in an indoor or artificial facility, provides limited nature connectedness. Worth noting is the idea that all individuals can contribute to environmental sustainability through active transportation, an idea substantiated by the following theoretical analysis of the adoption of this travel behaviour across four generations.

Table 1. The authors' mapping of key active and non-active transport modes onto the three operational scopes or boundaries.

SN	Transport Mode	Operational Boundaries			Attribute(s)	Description
		Scope 1	Scope 2	Scope 3		
Active modes of transportation						
1	Walking (EF)	No	No	No	Eco-friendly *	Walking without using any supporting product (e.g., canned energy drink or car)
2	Walking (PS)	No	Yes	Yes	Less eco-friendly **	Walking while using a product or driving to a point before starting to walk
3	Running (EF)	No	No	No	Eco-friendly	Running without using any supporting product
4	Running (PS)	No	Yes	Yes	Less eco-friendly	Running while using a product or driving to a point before starting to run
5	Swimming (EF)	No	No	No	Eco-friendly	Swimming without using any supporting product
6	Swimming (PS)	No	Yes	Yes	Less eco-friendly	Using a product while swimming or driving **** to a point before engaging in swimming
7	Skiing/surfing (EF)	No	Yes	Yes	Eco-friendly	Skiing or surfing without any supporting product
8	Skiing/surfing (PS)	No	Yes	Yes	Less eco-friendly	Using a product while surfing or skiing or driving to a point before surfing or skiing
9	Biking (EF)	No	Yes	Yes	Eco-friendly	Using a bicycle that is made of biodegradable or recyclable materials
10	Biking (LEF and PS)	No	Yes	Yes	Less eco-friendly	Using a bicycle that is made of traditional materials ***
11	Skating, skateboarding, roller skating (EF)	No	Yes	Yes	Eco-friendly	Using equipment that is made of biodegradable or recyclable materials
12	Skating, skateboarding, roller skating (LEF and PS)	No	Yes	Yes	Less eco-friendly	Using equipment that is made of traditional materials that are less eco-friendly or can result in non-biodegradable waste
13	Scooter, kick scooter/wheelchair (EF)	No	Yes	Yes	Eco-friendly	Using equipment that is made of biodegradable or recyclable materials
14	Scooter, kick scooter/wheelchair (LEF)	No	Yes	Yes	Less eco-friendly	Using equipment that is made of traditional materials that are less eco-friendly or can result in non-biodegradable waste
15	Rowing (EF and PS)	No	Yes	Yes	Eco-friendly	Using equipment that is eco-friendly and can, therefore, result in less or biodegradable waste
16	Rowing (LEF and PS)	No	Yes	Yes	Less eco-friendly	Using equipment that is made of traditional materials that are less eco-friendly or can result in non-biodegradable waste
Non-active modes of transportation						
17	Motorbike, car, ship, train, and aeroplane (EF)	Yes	Yes	Yes	Eco-friendly	A motorcycle made of recyclable/biodegradable materials and is 100% electric
18	Motorbike, car, ship, train, and aeroplane (NEF and PS)	Yes	Yes	Yes	Not eco-friendly	A vehicle that uses fossil fuels and is made of materials not biodegradable or recyclable

Note: Active transport modes shown (i.e., 1–16) do not involve the combustion of fossil fuels; the numbers 1–18 do not represent ranks or an order; mapping of transport modes onto the three operational boundaries was based on whether the transport behaviour involves the use of a product or vehicle, depends on a utility or energy source that emits greenhouse gases, and whether the productive involved is small, biodegradable, or recyclable; mapping was also based on the assumption that greenhouse gas emissions across the lifespan of fuel-dependent transport modes are more than emissions across the lifespan of active transport modes; "No" (i.e., colour green) means the boundary or scope does not apply to the corresponding transport type, and this suggests a zero or negligible footprint of the transport type; "Yes" (i.e., colour red) means the boundary applies to the corresponding transport mode; SN—serial number; PS—product-supported; EF—eco-friendly; LEF—less eco-friendly; NEF—not eco-friendly; * biodegradable (e.g., made of wood) or recyclable; ** not biodegradable or recyclable; *** traditional materials are raw or processed materials that are not recyclable or biodegradable; **** driving a vehicle that involves the combustion of a fossil fuel.

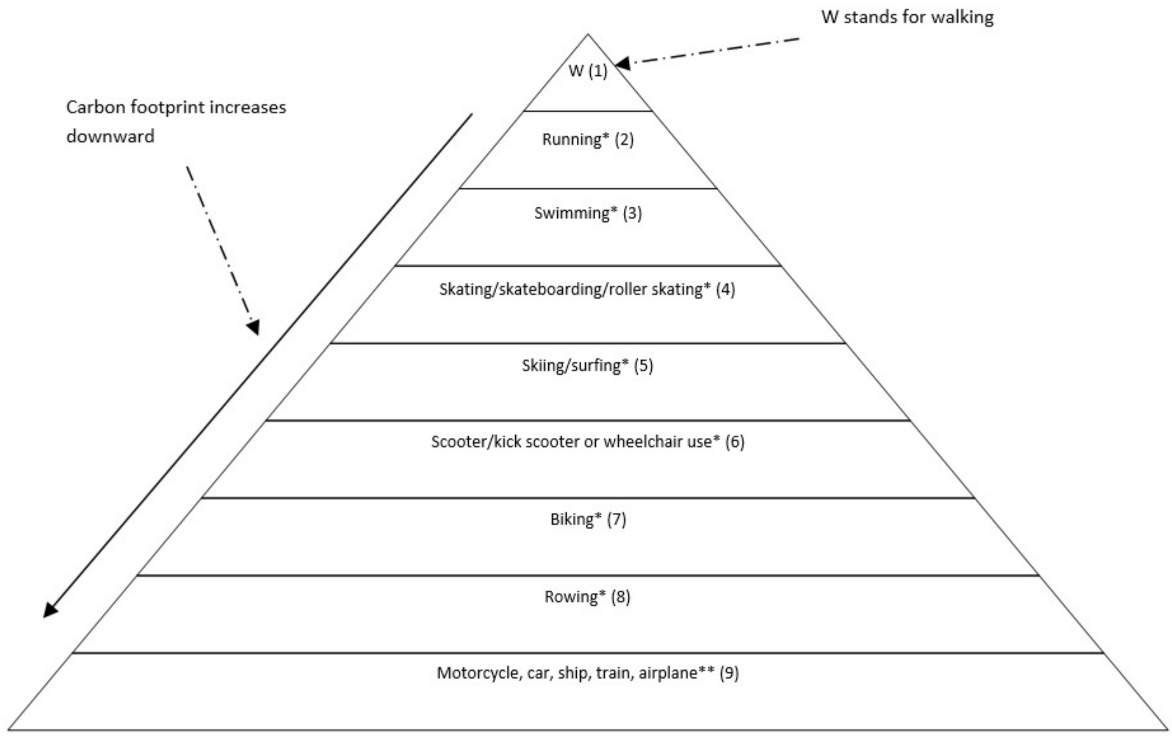

Figure 1. A hierarchy of potential environmental impact of active and non-active transport modes. Note: Active transport modes shown (i.e., 1–8) do not involve the combustion of fossil fuels; the hierarchy was developed based on whether the transport behaviour involves the use of a product or vehicle, depends on a utility or energy source that emits greenhouse gases, and whether the productive involved is small, biodegradable, or recyclable; the hierarchy also assumes that greenhouse gas emissions across the lifespan of fuel-dependent transport modes are more than emissions across the lifespan of active transport modes; size of the vehicle, equipment, or product is assumed to increase down the pyramid; ** Represent non-active or fossil fuel-dependent modes of transportation; * Active modes of transportation.

5. Theoretical Framework

The literature [27,29,31] to date suggests that active transportation behaviour is influenced by three categories of factors, namely, demographic (e.g., age, income, and gender), psychosocial (e.g., neighbourhood trust, safety, and social cohesion), and physical environmental factors (e.g., street connectivity and mixed land use). Income, for example, determines car ownership and whether one will choose driving over walking [28,37]. Neighbourhoods with highly interconnected streets are more likely to encourage walking and bicycling [29,38], and those with psychosocial factors such as safety offer a better contextual advantage for active transportation [29,39]. Yet, the extent to which these factors affect active transportation differs among age groups due to changes in living conditions experienced by the individual in ageing [39]. The Bioecological Systems Theory (BST) developed by Unrie Bronfenbrenner [40,41] implies that the onset of these changes starts in childhood.

The BST is a multi-level framework for understanding the influence of the above categories of factors on active transportation. The primary part of this system is the microsystem where young children begin life by developing relationships with parents and other close relatives. It provides a social climate where family norms and values are transferred by older ones to children in a gradual way, making it possible for younger ones to learn and apply family traditions. Children may grow to appreciate and enjoy biking to school owing to their exposure to a longstanding family tradition of biking to school. Studies have confirmed that children with active parents who travel to work through active transportation are more likely to walk or cycle to school [42,43]. Though the BST suggests that several other factors (e.g., family income) can influence the active travel of children, it implies that children begin to develop behaviours and habits through their subjection to relationships and norms in their immediate family environment. The main disadvantage at this stage is that children may not grow up with healthy behaviours (e.g., walking) if their immediate families do not value these behaviours. If family norms favour driving over walking, children would be influenced to cultivate the habit of using non-active transportation.

Beyond the microsystem, there are the mesosystem and exosystem that encompass a system of external relationships (e.g., teachers, and neighbours) intertwined with the child's immediate family [41]. These systems provide a wider social and physical environment, hereby referred to as the community, where knowledge and habits can diffuse between the family system, neighbours, and service providers, such as the school. From this viewpoint, active transportation among children may be co-influenced by the family, neighbours, and service providers. The wider social environment may support active travel through its qualities of cohesiveness, reciprocity, and safety [39], whereas teachers and social networks (e.g., friends and classmates) can encourage active travel [39,44] depending on norms within the community and their immediate families. As mentioned earlier, children and adolescents who are dependent on their parents are subject to influences from their family and community, so they would not perform active transportation behaviour if it were not a value in these social settings.

Before entering the third generation, children who grow into the second generation may enjoy enhanced autonomy and flexibility in decision-making because their parents may begin to recognise their improving maturity. In the third generation, therefore, parents may allow their adolescent children to make some decisions, including transport decisions. Thus, the second generation is in a stage where there is an onset of opportunities to exercise free will, monitored by mature members of the micro and mesosystems. If the child was well embedded in a family tradition of active transportation, for example, they might exercise free will in ways that translate into active transportation [43,44]. Yet, individuals in this generation may not have absolute autonomy, possibly because their parents are ambivalent about their life experiences.

In adulthood, individuals may have started an independent life, but they can maintain relationships across the three systems through regular communication and commuting with family members, workmates, and business partners. Autonomy and flexibility in decision-making may have reached an optimum level, enabling the individual to decide whether to pursue a lifestyle influenced by the family and other social systems in the first and second generations. Members of this generation are generally a working class who exercise control over their earnings and how to spend them through, for example, car ownership. Adults who grew up in a family or environment where active transportation was a shared hobby are likely to own a bicycle or similar equipment for active transportation. Such individuals, depending on how the three systems including the educational system influenced their pro-environment behaviour [19,27], may own cars but may only use them to travel long distances. The main disadvantage at this stage is that individuals may have new commitments (e.g., work) that may deprive them of social support and time for active transportation behaviour.

Between the first and third generations, the individual can adapt life experiences from social ties spanning the three systems. For instance, those who had left their family and community but were positively influenced to practice walking as a habit may continue to utilise past experiences to maintain walking. The opportunity to draw on the three systems (implicit in social ties and experiences from the previous community) is recognised by the Activity Theory of Ageing (ATA) [45,46]. The ATA asserts that ageing people can adapt their past experiences (e.g., cycling to school) and social networks to maintain physical activity. This process of life course adaptation occurs in a social context where skills and life experiences from social networks (e.g., parents or friends) are acquired through learning, observation, communication, and role modelling.

On the other hand, the Disengagement Theory of Ageing (DTA) argues that the ability to adapt past experiences to maintain physical activity and possibly stick to an acquired active transport behaviour dwindles in the ageing process due to a decline in the individual's resources (e.g., social ties and income) and physical functional ability in later life [46]. The DTA, thus, suggests that resources and physical abilities that may support active transportation may be insufficient in the fourth generation. As such, habits such as walking and cycling learned through the initial life stages may be discouraged by a decline in social networks (e.g., through the death of social ties) and physical functional capacity. Some researchers [39,46] and the ATA suggest, nevertheless, that individuals who maintain physical activity over the life course avoid this decline and maintain physical activity into later life. Individuals may maintain active transportation in the fourth generation if they started an active lifestyle earlier, ideally in the first generation and maintained it through the remaining stages. The ATA also insinuates that people can maintain autonomy in the fourth generation if they adapt past experiences rooted in the three systems of the BST across the lifespan.

Another factor that may influence active transportation across the four generations is a change in life goals necessitated by the ageing process [47]. For example, people in the fourth generation may decide to spend more time with closer social ties such as grandchildren and in-laws and avoid less important activities. This decision stems from older adults' future time perspective [48], which is about awareness of how short their remaining life is and a need to spend time on only activities and people who matter to them. This concept of future time perspective originates with the Socioemotional Selectivity Theory [49], which asserts that older adults may limit their social and physical environment through social disengagement by focusing on only a few valued relations and social activities associated with these relations. This behaviour may terminate the positive influence of demographic, psychosocial, and environmental factors on active transportation in later life. To explain, an older adult may give up social ties and activities in the community to spend more time with grandchildren through childcare at home.

Depending on the lifestyle of their social ties, nevertheless, older adults can maintain engagement with life through active transportation. Older adults who are psychologically and emotionally attached to their valued active grandchildren, in-laws, or surviving spouses may continue to perform physical activity (e.g., walking and cycling) necessitated by social activities. If individuals grew old in a family where active transportation was a tradition, their future time perspective would rather support the maintenance of active transportation [43], especially if this behaviour enhances their longevity, which they need to spend more time with their loved ones. An active family tradition makes it more likely for people in the fourth generation to maintain the willingness and ability to sustain active transportation. The above theoretical deductions suggest that all generations face barriers to active transportation and that even younger adults do not have a perfect chance to adopt active transportation behaviour.

6. Active Transportation Adoption: Are Older Adults Laggards?

Ageism against older adults in environmental activism is partly premised on the notion that older adults perform less pro-environment behaviour (i.e., active transportation) [19,23] and have generated a higher carbon footprint linked to non-active transportation over the life course [9]. As Table 2 suggests, however, every generation has unique barriers and opportunities for active transportation; opportunities for performing active transportation behaviour are uniquely counteracted in each generation, which is why the sustainability of active transportation over the life course is not necessarily higher in generations under 50 years. As the above theoretical framework suggests, the way opportunities and barriers in Table 2 play out in practice depends on context, characterised by the family and wider community from which learning and adaptive behaviour take place. In this section, the authors emphasise empirical evidence supporting this reasoning by reviewing studies on the relationship between age, pro-environmental behaviour, and active transportation.

Table 2. The authors' visualisation of the core characteristics of the four generations within the theoretical framework.

Group	Description	Core Attribute(s)	Possible Barriers	Possible Opportunities	Implications *
Children (generation 1)	Infants and other young children aged 0–12 years who cannot make decisions	Members live with parents or guardians and are subject to parents	(1) Little or no autonomy, and (2) dependence **** on parents that may limit active transportation	(1) Teachableness, and (2) opportunities to start learning from family, networks (e.g., teachers), and community **	Children do not make their own decisions, so their parents and immediate social environment may prevent them from choosing active transportation if they do not value this travel behaviour
Adolescents (generation 2)	Adolescents and teenagers aged 13–17 years who are living with parents or guardians	Members live with parents or guardians and are subject to parents but with improved autonomy vias-a-vis stage 1	(1) Improved but limited autonomy, and (2) insufficient independence from parents, which can prevent active transportation	(1) Youthful vigour or physical strength and (2) learning opportunities through mentoring, formal education, and positive norms (e.g., walking regularly for health)	Adolescents can draw on their physical strength to perform active transportation behaviour if their family and community provide relevant norms and model behaviours
Adults (generation 3)	Individuals aged between 18 and 49 years	Members are likely working, have optimum autonomy, and can make and act on personal decisions	(1) May leave family as well as the community and networks one grew up with, and (2) new commitments (e.g., work) necessitated by independence may prevent active transportation	(1) Independence, (2) income from employment, and (3) optimum autonomy	Adults can make personal decisions, but the pursuit of new goals (e.g., using a car) can prevent them from choosing active transportation, especially in the absence of support *** from previous networks
Older adults (generation 4)	Individuals aged 50 years or higher	Members may have retired; functional ability may decline, and autonomy may reduce due to a disability	May lose supportive social networks, income, or functional abilities due to ageing	(1) Rich life experience, (2) a future time perspective that may support active behaviours, and (3) close ties (e.g., grandchildren) to support engagement with life	Older adults may lose the physical functional ability and resources (e.g., previous social networks) needed to perform active transportation behaviour

* Implications of the barriers and opportunities for the individual's active transportation choices; ** The community represents the multilevel exosystem implicit in the BST that includes institutions (e.g., school and teachers), neighbourhood social environment, and the physical built environment; *** Support refers to positive experiences (e.g., family norms, positive influence from school and teachers, and favourable environmental conditions, such as safety and social support) that encourage or allow the individual to develop and grow with positive behaviours, such as active transportation; **** Dependence on parents is only positive if the family environment provides positive norms and values; otherwise, parents who do not value some behaviours (e.g., active transportation) may prevent their children from choosing it as a travel method.

The empirical literature to date provides mixed evidence regarding the relationship between age and pro-environmental behaviour. A cross-sectional study in Spain found pro-environmental behaviour higher among older adults [21], but two other studies in different countries found this behaviour is higher in younger adults [20]. In China, a cross-sectional study utilising data from 31 countries produced mixed findings, affirming that pro-environmental behaviour is not always higher in younger adults [23]. In a systematic review [20], 31 out of 33 studies reported mixed findings about the association between age and pro-environment behaviour, further affirming that younger adults do not perform higher pro-environment behaviour. This review revealed that older adults can perform higher pro-environment behaviour depending on personal and socio-environmental factors, which is congruent with the foregoing theoretical framework.

A study in the UK [19] found older adults, compared with younger adults, reported less active transportation time, but another study in Germany [26] reported older adults were more likely to perform active transportation behaviours (i.e., walking and cycling), compared with younger adults. In Taiwan, older adults were found to report more active transportation (i.e., cycling) [27] and two other studies [28,29] in Ghana and New Zealand have found older children are more likely to walk or cycle. Thus, the idea that younger people, compared with older people, perform higher active transportation behaviour is also not empirically supported.

Deductively, there is no consistent evidence that active transportation is higher in younger adults because of contextual differences (e.g., some may not grow up in a family or community with opportunities to perform positive behaviours), and differences in people's ability to learn and maintain active transportation over the life course. Because of this, ageing would limit or favour active transportation depending on the context. If so, older adults are not laggards when it comes to the adoption of active transportation, which means ageism against older adults in active transportation and environmental activism has no empirical basis.

7. Discussion

This review aimed to (1) develop a hierarchy for understanding the impacts of active and non-active transport modes on the environment and (2) analyse the adoption of active transportation between older and younger people.

Our analyses suggest that walking, running, and swimming are the only active transport modes with no or negligible carbon footprints. These three modes of transportation are on top of the pyramid or hierarchy, which indicates that they are the most environmentally friendly way to travel. Studies [50,51] recognise these modes of transportation as some of the best ways to travel without adversely impacting the environment, but our review adds to this recognition by proposing the hierarchy and implying that these three transportation methods would produce the least carbon footprint. The hierarchy suggests that active transport modes can generate carbon footprints depending on their size and how they are designed and used. Given this understanding, researchers are encouraged to rather promote active transportation with no or negligible emissions of greenhouse gases and avoid implying that all forms of active transportation behaviour are protective of the environment. Researchers have generally framed active transportation as a pro-environment behaviour [37,50,51], but our analyses reveal a need for them to acknowledge the limitations of active transport modes with a carbon footprint.

The general perception that older adults adopt active transportation less and would, therefore, contribute less to a safer environment is based on mixed and inconclusive evidence. As such, there is no basis for the ageist views reported in the literature [7,9] against older adults in environmental activism. If so, more generalisable empirical evidence is needed on the relationship between active transportation adoption and age, and any future studies assessing this relationship ought to consider the relative carbon footprints of the different modes of active transportation, without which it would be impossible to accurately determine each generation's transportation-related carbon footprint and its impact on the environment. As our review suggests, the adoption of active transportation is not impossible among older adults, though this segment of the population may have the least physical functional ability for performing active transportation behaviour [39,46]. Stakeholders are, therefore, encouraged to include older adults in transportation-related initiatives against climate change. Older adults may contribute unique and complementary experiences for advancing these initiatives.

7.1. Implications for Practice

According to the theoretical framework, communities comprising the family system, service providers (e.g., schools and hospitals), built environment, social networks, and psychosocial factors (e.g., safety and social cohesion) are the embodiment of micro-, meso-, and exosystem factors that enable people to learn and maintain positive behaviours over the life course. Some of the specific factors within these systems that support active transportation across the lifespan are family income, norms favouring healthy behaviours, walkability, and services, such as formal education [27,29,31]. Stakeholders should create inclusive communities and provide services enabling and empowering individuals to overcome barriers to active transportation across their lifespan. Public health education can also be implemented to influence families for developing pro-environment traditions through which their ageing members learn to maintain active transportation behaviour as a habit.

As the ATA suggests, older adults can maintain active transportation in later life if the above measures provide contexts where they can adapt their life experiences across the lifespan. Both the ATA and DTA agree that people become inactive in the ageing process because of a decline in resources and functional ability, but this decline can be avoided through lifelong adaptation of positive experiences acquired through learning in one's family and community. Learning in this vein can be encouraged through public health education or promotion in which individuals are conscientised to practice healthy behaviours, such as walking and cycling [52]. There is, thus, a need for scaling up public health promotion and education programmes intended to create awareness about the role of absolute active transportation in the fight against climate change.

As the hierarchy suggests, people's carbon footprint depends on whether vehicles or products used in their active transportation are biodegradable, recyclable, or large. If possible, manufacturers should prioritise products that are biodegradable, recyclable, and small. They may also consider avoiding the dependence of these products on utilities or energy sources that emit greenhouse gases. If products worn or used during active transportation do not emit any greenhouse gas or eventually become part of environmental waste, most or all active transport modes would generate a zero-carbon footprint. This recalls a need for individuals to properly dispose of waste during active transportation or use environment-friendly products during active transportation.

7.2. Limitations and Future Research

This review included 26 documents from two searches, but an analysis of the relationship between these documents was beyond the scope of our narrative review. Future systematic reviews discussing this relationship are needed. To meet our review goal, we focused on documents exclusively reporting a transportation type and a carbon footprint relating to it. Hence, the number of articles included in this review may be smaller than the number of studies based on active transportation in general. The active transportation types on top of the pyramid (e.g., walking) are not necessarily carbon-free as humans may wear clothes that produce greenhouse gases when walking or running. By referring to them as methods with a "zero-carbon footprint", we meant that they produce the least greenhouse gases and are the most sustainable alternatives for the earth. A more objective way to develop the hierarchy is to rank the transport modes based on their estimated carbon footprints. The literature, however, does not provide standard carbon footprints for transport modes, a shortcoming that future research should remedy. Similarly, this review does not estimate the carbon footprints of the various transport modes due to the non-availability of relevant data. Future researchers are encouraged to provide these estimates, preferably using objectively generated data. Future studies may also assess the validity of the hierarchy by comparing the carbon footprints of transportation types within the hierarchy. The authors' evaluation of product size may not be consistent across contexts and manufacturer niche markets. For instance, a bicycle for adults may be larger than a scooter for young children. Decision-makers should consider these inconsistencies in assessing and using the pyramid.

8. Conclusions

Active transportation can add to atmospheric greenhouse gases and is, therefore, not always environmentally friendly. Active transport modes that may have a zero-carbon footprint are walking, running, and swimming without a product. There are mixed and inconclusive findings regarding the potential effect of age on active transportation and pro-environment behaviour; hence, ageist stereotypes against older adults in environmental activism and active transportation are unwarranted and would weaken the impetus needed to overcome climate change. Younger and older people can avoid a carbon footprint if stakeholders can design the built environment and roll out policies that maximise the diffusion of knowledge and positive active transportation experiences in the family and community. Policies need to be rolled out to encourage families and communities to adopt active transportation behaviour as a culture. Public health education programmes aimed at encouraging individuals to practice active transportation behaviour over the life course are imperative and should be infused into public health policy. Manufacturers are encouraged to prioritise the production of active vehicles (e.g., scooters) that are biodegradable, recyclable, and small.

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Abbreviations

ATA	Activity Theory of Ageing
BST	Bioecological Systems Theory
DTA	Disengagement Theory of Ageing
MeSH	Medical Subject Headings
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
SPIDER	Sample, Phenomenon of Interest, Design, Evaluation, Research type
UK	United Kingdom

Appendix A

Table A1. The review workplan.

Review title	Active and Non-Active Transportation and Associated Carbon Footprints
Start and end date	1–15 April 2023, (2 searches were performed; the first one was performed on the 1st of April and the second one on the 15th of April).
Research question	What are the potential carbon footprints of active and non-active transport modes?
Condition being studied	Transport modes (i.e., air, land, and sea) and their associated carbon footprints
Search Strategy	
Eligibility criteria (based on SPIDER)	
Sample	All individuals and age groups (to make an intergenerational analysis possible)
Phenomenon of interest	Transport modes accompanying information about their carbon footprints or carbon-dioxide-related emissions
Design	Mixed (qualitative and quantitative)
Evaluation	The relative amount of greenhouse gases produced by each transportation type
Research type	Reviews, primary studies, studies using secondary data, and narratives
Language	English

Table A1. *Cont.*

Date restrictions	No date restriction
Exclusion criteria	Documents published in other languages apart from English, not peer-reviewed, not reporting a transportation type and its carbon footprint, and not published by journals indexed by SCOPUS, Web of Science, or PubMed
Inclusion criteria	Published in English
	Reported transportation type linked to its carbon footprint or greenhouse gas emission
	Peer-reviewed
	Published by journals indexed by Scopus, Web of Science, or PubMed
Geographical scope	Documents from anywhere in the world
Databases	
Essential	PubMed, CINAHL, PsychInfo, ProQuest
As relevant to the subject:	Google Scholar, SCOPUS
Search terms	Transportation, "active transportation", "carbon footprint", "greenhouse gas emissions", association, health, age
Search results	Search 1 = 205; Search 2 = 2

Note: SPIDER—Sample, Phenomenon of Interest, Design, Evaluation, Research type.

Appendix B

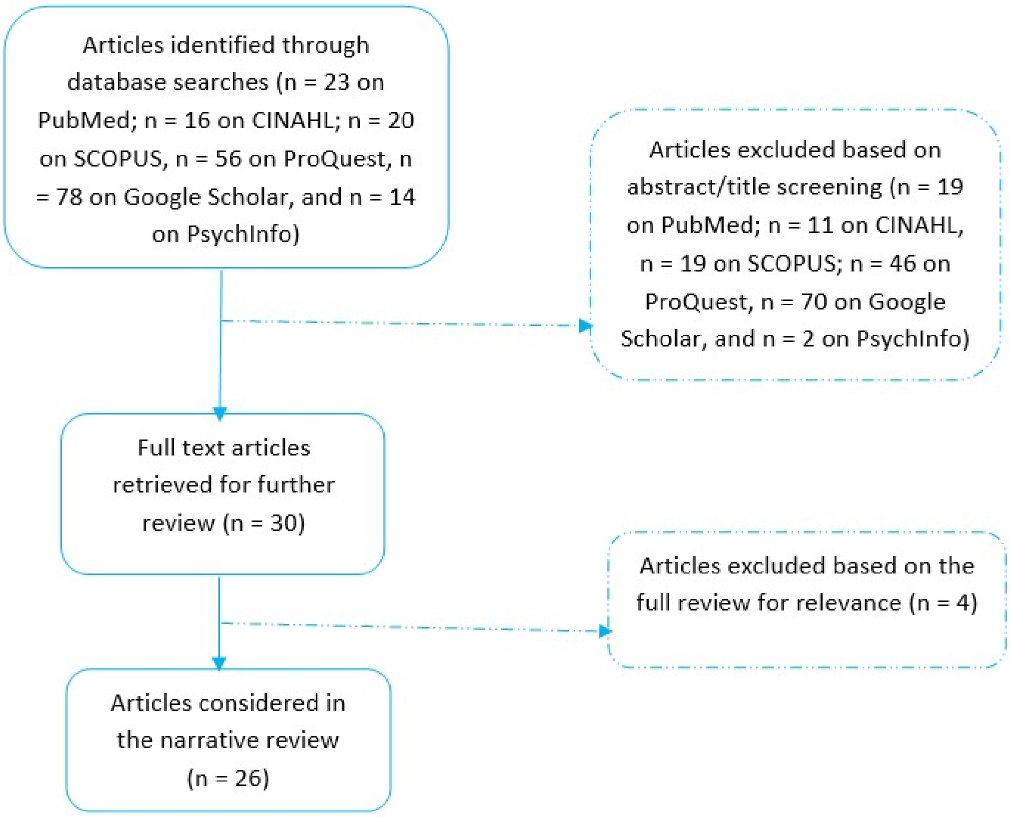

Figure A1. The PRISMA flowchart.

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