Carbon Footprints of Active and Non-Active Transport Modes

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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. This definition suggests that a carbon footprint can be generated directly or indirectly by an individual through daily behaviours.

carbon footprint active transportation older adults generations

1. Introduction

The foregoing definition makes Wicker's framework [1] for assessing carbon footprint ideal for the research. 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 [2][3]. 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 [4], whereas Ghana sets it at 60 years [5]. Globally, the minimum old age is 50 years [4][6]. Although the minimum age of 50 is not a good indicator of the individual's health and physiological conditions [6], it is a globally acceptable baseline. Thus, older people are operationally defined as individuals aged 50 years or higher and are the fourth generation.

2. 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 [7]. 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 [8] 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.

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

SN	Transport Mode	Operational Boundaries			Attribute(s)	Description
		Scope 1	Scope 2	Scope 3		
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-

SN	Transport Mode	Operational Boundaries			Attribute(s)	Description
		Scope 1	Scope 2	Scope 3		
						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

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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 (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 [9]. 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 [10], 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.

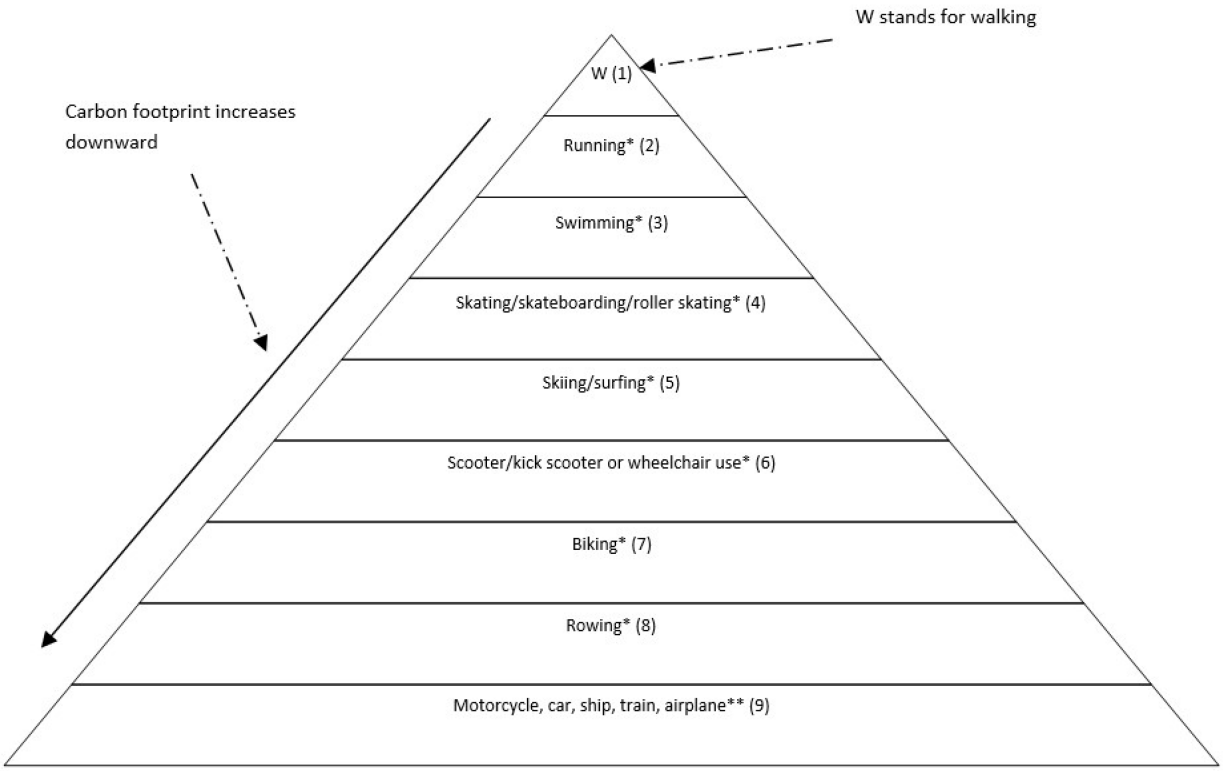

Figure 1. A hierarchy of potential environmental impact of active and non-active transport modes. Note: Active transport modes shown (i.e., 1–8) do not involve the combustion of fossil fuels; the hierarchy was developed based on whether the transport behaviour involves the use of a product or vehicle, 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.

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