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Sustainable Personal Transport Modes in a Life Cycle Perspective—Public or Private?

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Abstract: Life cycle-based studies endorse public transport to cause lower environmental pressures compared to a private car. However, a private car can cause lower environmental pressure when a public vehicle (bus or train) runs on a lower occupancy during an off-peak hour. This fact should be the basis for a more profound debate regarding public versus private transport. Many transport interventions are striving to reduce the number of car transports. To reach this goal, passengers need attractive alternatives to their reduced number of car travels (i.e., attractive public transport). This study aimed to develop a model allowing us to estimate potential environmental gains by changing travel behavior. A passenger travel model was developed based on life cycle inventories (LCI) of different travel modes to calculate environmental footprints. The model was applied in an intervention of public transport through temporary free public transport. The intervention was successful in significantly reducing the number of car transports (12%). However, total passenger kilometer travelled (PKT) increased substantially more, mainly by bus, but also train, bicycle and walking. The total energy, carbon and nitrogen oxide footprints were slightly increased after the intervention. If the commuters were assumed to travel during peak hours or the number of public transports were not affected by the increased number of commuters, the overall environmental footprints decreased. Our conclusions are that transport interventions are very complex. They may result in desired changes, but also in altered travel behavior, increasing overall impact. Thus, a very broad evaluation of all transport modes as well as potential positive social influences of the transport intervention will be necessary.

Keywords: life cycle assessment; environmental footprints; public transport; transport interventions; sustainable transport

1. Introduction

Climate change is considered one of the greatest global challenges that we are currently facing. The transport sector is the most important consumer of oil products [1] and responsible for approximately 23% of global energy related carbon dioxide and 14% of greenhouse gas (GHG) emissions [2]. The rate of GHG emissions from the transport sector is increasing faster than emissions from other sectors [3]. The global GHG emissions of transport (both passenger and freight) have increased around 31% from 2000 to 2016 [4]. Among the transport activities, passenger travel has increased more rapidly compared to other transports [3]. On a global basis, total passenger kilometer travel (PKT) has increased 74% from the year 2000 to 2016 (32.2 trillion to 56.3 trillion PKT) [3,5].

The global share of transport sector GHG emissions by mode in 2015 was 3% by rail, 4% by two-and-three wheelers, 5% by buses, 11% by shipping, 11% by aviation, 21% by trucks and 45% by cars or light-duty vehicles [6]. In Sweden, cars emitted approximately 67% of the total GHGs emitted by road traffic in 2017 [7]. According to the statistics [7], the emissions by the car mode have been decreasing since 2000 (approximately 12.5 million tons CO_2eq emitted in 2000 compared to approximately 10 million tons in 2017). The car-related emissions could decrease even further by shifting mode from private cars to public transport according to a recent study [8].

An extensive description of mass transport systems, their functions and functioning as well as environmental challenges and different mitigation actions was presented in a book by Abdallah [9]. General policy and management aspects of sustainable commuting have been investigated by Eliasson and Proost [10] and Ramjerdi et al. [11]. Eliasson and Proost [10] found that there is a risk of overemphasizing the impact of different single type interventions if dynamic market responses are not taken into account (different types of rebound effects such as special and intertemporal changes in transport consumption). A main finding of Ramjerdi et al. [11] was that parking fee policies for fossil-fueled cars is a very effective policy option. For Vienna, Buehler et al. [12] reported a reduction in car transport share of total personal transport from 40% to 27% between 1993 and 2014. A key to success was a coordinated package of mutually reinforcing transport and land-use policies making car use slower, less convenient and more expensive, and at the same time improving conditions for walking, biking and public transport. An interesting and socially oriented discussion of sustainable commuting was presented by Modarres [13]. He argues that the physical expression of cities may have influence on the social coherence and on the sustainability of commuting. This is because people with little money are "forced" to live far from city centers and thus will have to travel longer distances, often by car.

Various kinds of initiatives and interventions have been studied to assess modal shifts from car travel to public transport as well as to understand behavioral/psychological mechanisms for such changes [14–18]. There have also been many life cycle-based studies published, aiming to assess environmental footprints of different travel modes and trying to demonstrate how much environmental benefit could be gained from such modal shifts [19–23]. However, the direct link of travel interventions or behavioral change with life cycle-based environmental footprints is weakly explored in the literature. Previous studies accounted for the environmental gains by a travel intervention considering either only the operational phase (fuel saved and related environmental gain [24]) or a single environmental footprint in a life cycle perspective, (e.g., carbon footprint (CO_2eq) [25]).

A comparison of different travel modes in a life cycle perspective in the literature demonstrates that public transport has lower environmental pressures compared to those of a private car [22,23]. However, using a private car for personal transport can cause lower environmental pressure when a bus runs on a lower occupancy during an off-peak hour. This fact should be the basis for a more profound debate regarding public versus private transport. Many transport interventions are striving to reduce the number of car transports as stated above. To reach this goal, passengers need attractive alternatives to their reduced number of car travels (i.e., attractive public transport). Improvements on a micro scale could have an important environmental impact on the macro scale [26,27]. Thus, it is important to assess how improvement actions on a small scale would affect a bigger system. For example, travel interventions could reduce car travel; however, it is important to assess how the reduced travel would affect other transport modes.

The present study attempts to develop a life cycle assessment-based passenger travel model (PTM) that can assess intervention effects or change of an individual passenger, company, institute, city or even country. The development of the model is a subproject to support a project on energy efficient transport aiming to determine how behavioral intervention programs should be designed to be as effective as possible to achieve sustainable and energy-efficient travel mode choices. The project attempts to develop methods to produce new knowledge about how individuals are affected by various intervention programs for energy-efficient travel, and what type of intervention programs has the greatest impact on the choice of energy efficient travel behavior of a particular individual or group of individuals. This would create a better understanding of how interventions can be designed for more energy/environmental-efficient travel. The project runs in cooperation between Service Research Center (CTF) at Karlstad University and Department of Sustainable Development, Environmental Science and Engineering (SEED) at KTH Royal Institute of Technology Stockholm, and collaboration with two regional public transport providers in the south and west of Sweden.

Aims and Objectives

The project aims to develop a life cycle inventory-based passenger travel model and simulate behavioral intervention programs to assess sustainable and energy-efficient travel mode choices. The objectives of the study were to:

1. Develop a life cycle inventory-based model for different transport modes—a transport mode model—to calculate environmental footprints of different transport modes.
2. Develop a passenger travel model and allow coupling of it to the transport mode model.
3. Apply the combined model to assess a public transport intervention program to address the discussion around public and private transport.

2. Materials and Methods

The life cycle-based passenger travel model (PTM) consists of two models: (i) a transport mode model (TMM) and (ii) a passenger model (PM). The transport mode model is a compilation of different transport modes with life cycle inventories (LCI) following the life cycle assessment standard of International Organization for Standardization (ISO) 14040/44. It allows us to compare different transport modes in terms of different environmental footprints (e.g., energy footprint). On the other hand, the passenger model is designed to assess various changes around travel behaviors and management of vehicles. The passenger model is then coupled to the transport mode model to account for the environmental footprints as shown in Figure 1. The coupling between the two models are documented in the Supplementary Materials.

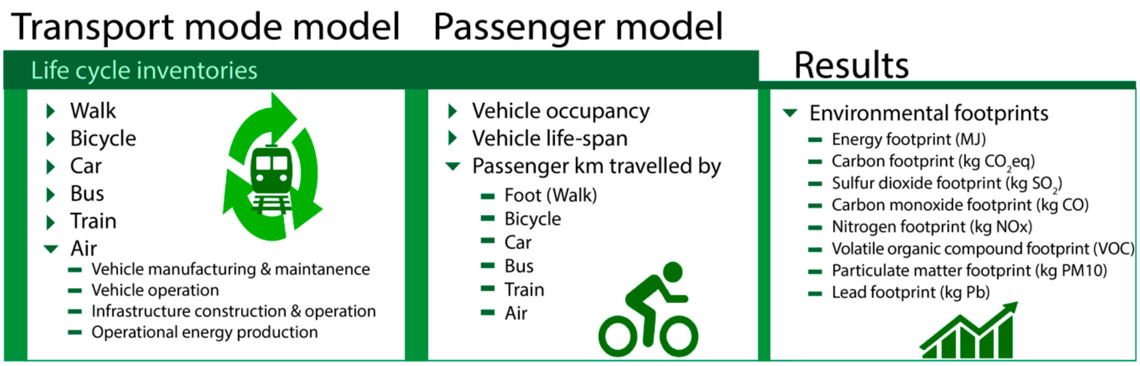

Figure 1. Conceptual model of the passenger travel model.

2.1. Transport Mode Model (TMM)

An Excel-based model was developed for different transport modes. A life cycle inventory-based (LCI-based) environmental footprint method [28] was adopted to develop the model in order to assess different transport modes. The following environmental footprints were calculated: carbon footprint (CO_2eq), energy footprint (MJ), carbon monoxide footprint (CO), nitrogen oxide footprint (NOx), sulfur dioxide footprint (SO_2), volatile organic compound footprint (VOC), particulate matter footprint (PM10) and lead footprint (Pb). The functional unit of the transport mode is passenger kilometer travelled (PKT) by the specific mode. The transport modes included in the model are: walk, bicycle, car, bus, train and air.

The environmental footprint was calculated by summing up the footprints of all inventories in a life cycle perspective. Life cycle inventories for each transport mode were divided into the following categories: (i) vehicle manufacturing and maintenance, (ii) vehicle operation, and (iii) infrastructure construction and operation. Vehicle manufacturing and maintenance includes life cycle of vehicle production, maintenance, repair and parts required for the maintenance (e.g., tires). Vehicle operation includes life cycle of operation energy production (e.g., gasoline, diesel) and vehicle operation (e.g., running, startup, brake wear, tire wear, evaporative emissions during operation, idling). Infrastructure construction and operation comprises life cycle of infrastructure construction, infrastructure maintenance, vegetation control, lighting during dark hours, and parking. The data of the life cycle inventories of different transport modes were collected from the EcoInvent 2.2 (EcoInvent, Zurich, Switzerland) database and data from the literature [8,21–23] (for detailed information about the inventories and categorization for each transport mode and data sources, see the Supplementary Materials).

2.2. Passenger Model (PM)

The passenger model was developed based on a sensitivity analysis (see the most sensitive parameter in Figure 3), where the most significant contributions to the environmental footprint for a certain transport mode was studied. The sensitivity analysis was conducted by increasing (also decreasing) a parameter value up to 100% while keeping other parameters at their default values. Such an approach would allow a passenger (as well as authorities and business) to simulate changes of the most influential parameters of a certain transport mode and see the influence on the environmental footprints. Vehicle life-span and vehicle occupancy (if more than one person can occupy a vehicle) were found to be the most sensitive parameters for the size of environmental footprints of each transport mode. These two aspects of each transport mode provided the basis for developing the passenger model. The model was designed in a modular way to allow expansion. The coupling between the PM and TMM were established by Equation (1) to account for environmental footprints of a commuter.

$$EF_{c,i} = \left(\sum_{j.k} \frac{PKT_C * EF_d * O_d * LS}{O * LS_d} + \sum_{j.l} \frac{PKT_C * EF_d * O_d}{O * LS_d} \right) \quad (1)$$

$EF_{c,i}$ represents environmental footprints of a commuter where i represents indicator for environmental footprint (e.g., carbon footprint, energy footprint), PKT_C stands for passenger kilometer travelled by a commuter, EF_d represents environmental footprint of an inventory (e.g., production of vehicle) for default parameter settings of the model, j represents each travel mode, k represents inventories related to vehicle manufacturing and maintenance, l represents inventories related to vehicle operation and infrastructure, O represents occupancy where d stands for default parameter values of the model, and LS represents life span of a vehicle.

2.3. Temporary Free Public Transport Intervention

A temporary free public transport study was performed throughout the county of Värmland (Sweden) to examine the intervention for increasing public transport aiming at understating psychological mechanisms for change and effectiveness of temporary free public transport on car-use behavior [29]. The county ran a project involving 14 companies and institutions in order to increase an accessibility of public transport to the workplaces for the commuters. Online surveys were distributed among the employees of the companies and institutions offering each participant a 30-day free public transport ticket. The details of the participants are presented in Table 1.

Table 1. Details of the participants in the project [29].

Variable		Number of Participants	Min–Max	Mean
Age			25–77	48
Gender	Female	103		
	Male	87		
Distance between home and work (km)			0.5–125	23.6
	0–9.9	78		
	10–19.9	22		
	20–29.9	26		
	30–39.9	25		
	40–49.9	12		
	Above 50	27		

A pre-study was conducted before the 30-day free transport intervention and a post-study four weeks after completion by sending questionnaires around demographic details, experience of the temporary free public transport, travel modes before and after, and other behavioral, psychological and general remarks (see details of the questionnaires in [29]). In the present study, average travel distances of a commuter in different transport modes were estimated based on the responded travel distances and modes by the commuter in the pre- and post-studies. If a commuter used combined transport modes, it was assumed that (i) the average walking distance between a station and home as well as between a station and the workplace was 1 km, (ii) an average bicycle use distance was 5 km, and (iii) a commuter would travel by train when the distance between home and work was farther than 50 km.

3. Results

The Excel-based passenger travel model, which was developed for the present study, allows a user to calculate environmental footprints in a life cycle perspective for the user's travel behavior. The user of the model can be an individual, a household, a company, a city or even a nation. The input parameters for vehicle occupancy, life-span and the mode of transport can be adjusted according to the user's behavior. If the user is not aware of an input parameter (e.g., life-span of a bus), the model provides a hint about the default value for a certain transport mode in the model, which is an average value for Swedish conditions in 2019. The model is designed in a modular way so that a user can extend the model according to the user's need (e.g., accounting for environmental footprint of land use, or transport mode of an electric car). The passenger travel model was in our case applied to assess the environmental footprint consequences of the temporary free public transport intervention held in the county of Värmland.

3.1. Transport Mode Model

The transport mode model was developed based on the life cycle inventories for the following transport modes: air, train, bus, car, bicycle and walk. Figure 2 illustrates the environmental footprints of different transport modes per passenger kilometer travelled (PKT). Among the different transport modes, car shows the largest environmental pressure for most of the footprint categories, while walk shows the smallest environmental pressure. Bicycle is second in the ranking for a low environmental footprint. Bus shows the second highest value for most of the environmental footprints, even higher than air. Train mode shows lower environmental footprints compared to bus and car.

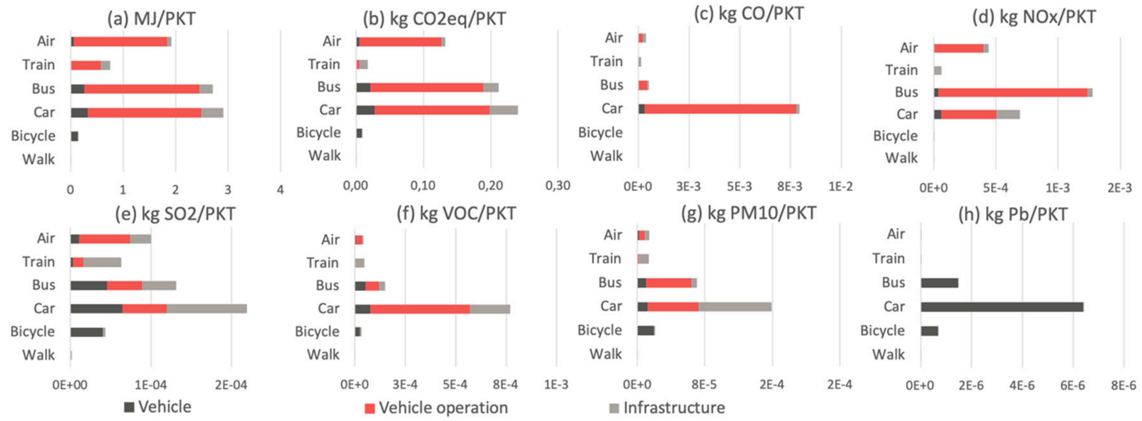

Figure 2. Environmental footprints of different transport modes in a life cycle perspective per passenger kilometer travelled (PKT): (**a**) energy footprint, (**b**) carbon footprint, (**c**) carbon monoxide footprint, (**d**) nitrogen oxide footprint, (**e**) sulfur dioxide footprint, (**f**) volatile organic compound footprint, (**g**) particulate matter footprint and (**h**) lead footprint.

The use/operational phases of the vehicles/transport modes show the largest contribution to environmental footprints. The environmental footprint for construction of infrastructure is—for most of the transport modes—slightly higher compared to the manufacturing of the vehicles for a majority of the calculated footprints. An exception is the bicycle transport mode, where the manufacturing footprints are higher than the ones for constructing infrastructure. A very special case is the environmental footprint for lead. Here, the entire environmental footprint is created during the manufacturing of the vehicles (Figure 2h).

3.2. Passenger Model

We made a sensitivity analysis of the input parameters related to the life cycle inventories of the transport mode model. The life span of the vehicles and occupancy (i.e., people in the vehicle) give the most important contributions to the environmental footprint. Figure 3 presents the sensitivity of the environmental footprints to changes in the life span and the occupancy of car, bus and train. According to the figure, occupancy is the most important parameter in influencing the environmental footprints of the transport mode model. If the occupancy is half of the default values (i.e., average values for the Swedish case), 1 passenger kilometer traveled by a bus shows larger contributions to energy, carbon and nitrogen oxide footprints compared to a car. However, car transport mode is the worst for carbon monoxide, sulfur dioxide, lead, volatile organic compound, and particulate matter footprint (Figure 3). It is important to notify that 50% of average occupancy for the car was set to 1.0 from a practical perspective since there needs to be at least 1 person in a car to run it.

If we focus particularly on energy and global warming potential, a car can be recommended when occupancy level is half of the average value (or smaller) for the bus mode. The average occupancy in a bus is 10.5 persons while the total number of seats on an average bus is 40. Broadening the perspective to other environmental footprints, car mode should not be promoted. Train transport mode shows lower values for all the footprints in Figure 3 compared to the transport modes of car and bus. Among the environmental footprints, the train transport mode is the most favorable for global warming potential (cf, carbon footprint, Figure 3b) due to the low carbon intensity of the Swedish electricity system [28].

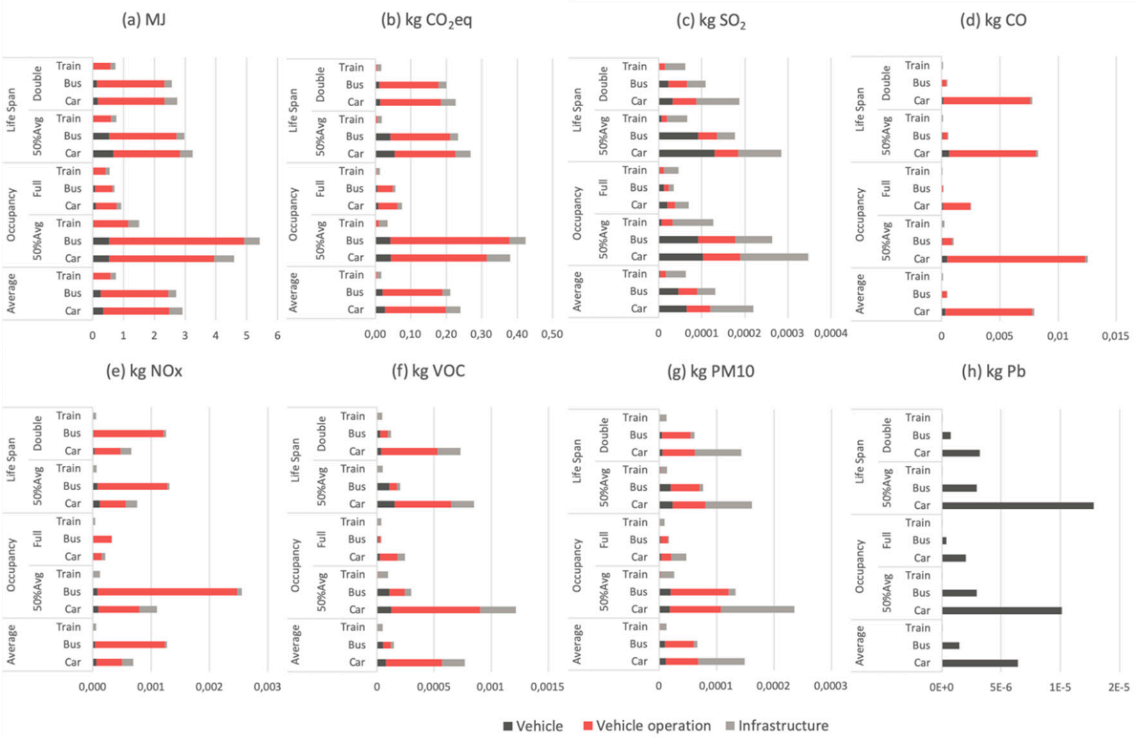

Figure 3. Sensitivity of the environmental footprint for 1 passenger kilometer (PKT) to simulated changes in life span and occupancy for car, bus and train: (**a**) energy footprint, (**b**) carbon footprint, (**c**) sulfur dioxide footprint, (**d**) carbon monoxide footprint, (**e**) nitrogen oxide footprint, (**f**) volatile organic compound footprint, (**g**) particulate matter footprint and (**h**) lead footprint.

Comparing the sensitivity of the environmental footprints per PKT to changes in occupancy and life span of the vehicles with the average or default parameter settings of the model, an interesting observation can be made: Changing the life span of the vehicles affects the environmental footprints of manufacturing while changing the occupancy affects the operational phase. Since the life span and occupancy cover the vehicle management and operational management in the use phase, the passenger model is designed to allow coupling of the user inputs with the occupancy and life span.

3.3. *Application of the Model to the Intervention*

We developed and applied the passenger travel model to assess the expected environmental gains of the temporary free public transport intervention. Figure 4 illustrates the before and after effect of the intervention in terms of yearly environmental footprints (Figure 4a–h) and commuter travel distance in different transport modes (Figure 4i) of an average commuter. The study was focused on the accounting of commuters' travel related to work. According to the figure, the total environmental footprints of sulfur dioxide, carbon monoxide, volatile organic compounds, particulate matter and lead decreased after the intervention.

However, the total environmental footprints of energy, carbon and nitrogen oxide have increased after the intervention. In those environmental footprints, car travel shows decreased footprints after the intervention, while footprints of the travel by bus increased significantly after the intervention. Footprints of train did not change after the intervention, but footprints of bicycle increased after the intervention. The intervention reduced the car footprints by around 10%. However, the environmental footprints of energy, carbon and nitrogen oxide by the public transport have increased significantly, around 50%.

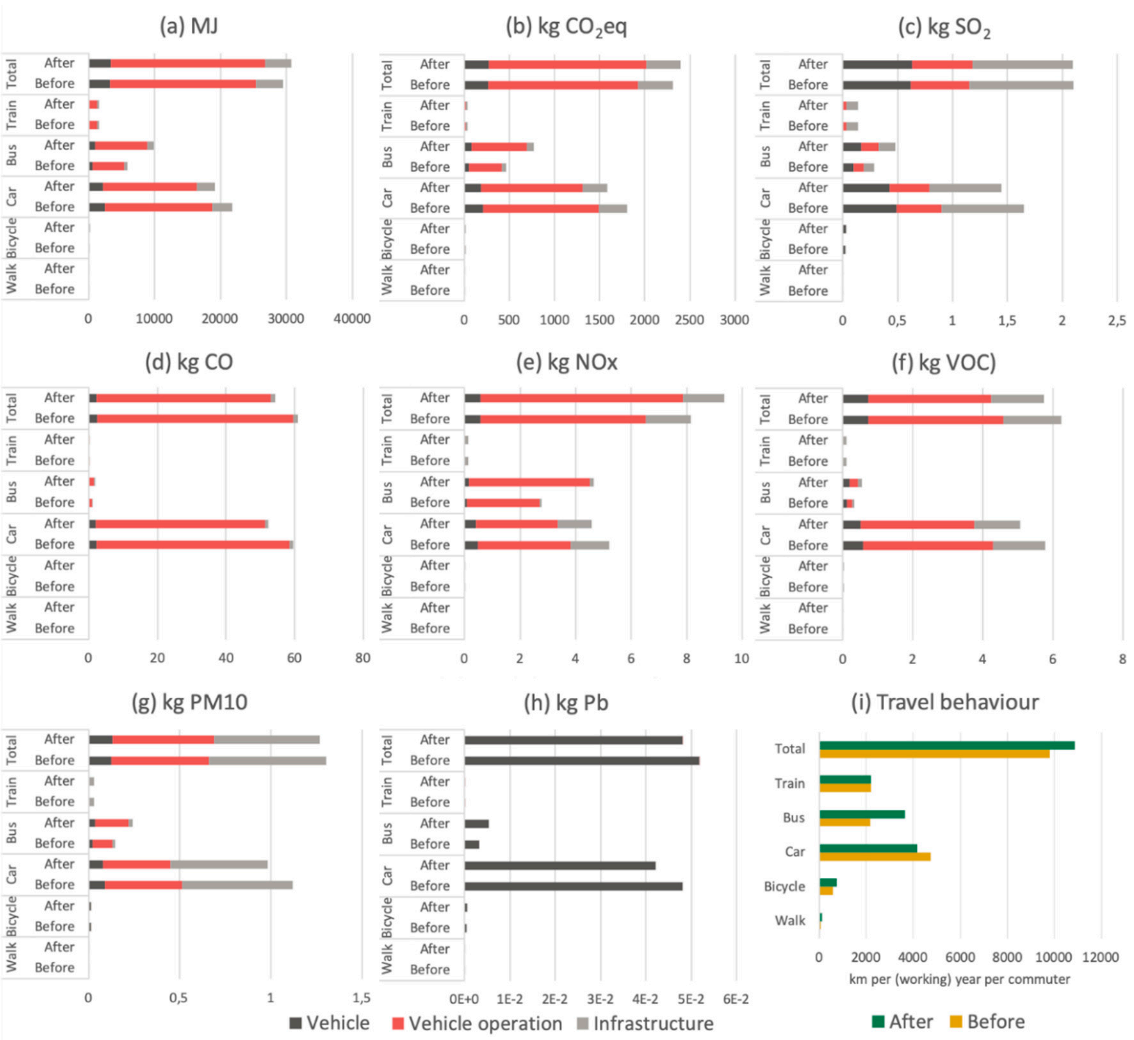

Figure 4. Before and after effects of the temporary free public transport intervention to (**a**) energy footprint, (**b**) carbon footprint, (**c**) sulfur dioxide footprint, (**d**) carbon monoxide footprint, (**e**) nitrogen oxide footprint, (**f**) volatile organic compound footprint, (**g**) particulate matter footprint, (**h**) lead footprint and (**i**) travel behavior to different transport mode.

Looking at the travel behavior (Figure 4i), the total travel distance in the yearly working days in passenger kilometer increased by 11% after the intervention, while car dropped by 12%; walk, bicycle and bus increased by 64%, 25% and 67% respectively; and train remained the same as before. Thus, the reduced car travel rebounded in the bus travel by increasing significantly after the intervention.

4. Discussion

4.1. The Intervention and Public Versus Car Transport

The significant increase in the bus mode PKT after the intervention can be explained by the freedom of a monthly ticket, which allows a commuter to travel extra kilometers without paying extra. It can also be assumed that the bus travel increased partly because bus routes are not optimized for off-peak hour travel, and the commuters had to travel longer distances by bus compared to car. However, these explanations should be taken with some caution as the increased number of trips may be due to other reasons not assessed in the surveys. People have many other considerations than just the function of transport and the environmental consequences of their choices (which is the core of this study). For example, travel is sometimes an important activity in itself, and not just a means to an end [30]. We also know from recent research that travel and travel experiences correlate with wellbeing and quality of life, both among adults [31] and children [32], and that travel is related to social inclusion in society [33]. Travel may thus have positive effects on people's daily life. Therefore, in addition to evaluating environmental consequences in travel interventions, it is also important to consider other aspects of value. Bearing that in mind, the focus of this paper was primarily the environmental consequences related to different choices of travel mode.

Our study shows that the temporary free public transport intervention in the county of Värmland, with the aim to promote public transport over car, most probably resulted in larger energy and carbon footprints, contrary to the expectations. The effect of the intervention was accounted for considering default/mean values in the model for occupancy in buses (default/mean seats in the model was set to 10.5 out of total 40 seats) and trains (146 out of 200 seats). If we consider that the commuters travel in the peak hours when the buses and trains run with full occupancy, the energy, carbon and nitrogen oxide footprints decreased after the intervention, as shown in Figure 5. It can also be argued that if the number of scheduled bus transports in the county of Värmland were not affected by the increased number of commuters, the overall environmental footprints decreased. Other environmental footprints in Figure 5 also decreased after the intervention. This indicates that promoting public transport over a car is environmentally beneficial even though it causes a significant rebound in average passenger kilometers (i.e., approximately 590 PKT reduced in car travel caused 1500 PKT increase in the bus transport). The regular schedules of bus lines in the county were not changed during the intervention. However, we do not have any information if there were any specific events during the intervention that led to changes in routes or extra buses.

The application of the intervention study to the passenger travel model indicates that the policy makers or management staff around transport systems should consider the effects on the connected systems before improving the core/focused system. For example, reduced car travel is good for the environment, but what would be an effect on the other transport modes? The temporary free public transport intervention showed that the 12% reduction in car travel environmental footprint caused an increased footprint in bus (67%), bicycle (25%) and walk (64%). The increased amount in bicycle and walk can be considered as co-benefits for health. Also, environmental footprints per PKT in those modes are small (Figure 2). However, the significant increase in the bus mode needs to be controlled. Otherwise, the rebound on the bus might offset the environmental benefits of public transport.

Similar to our findings, tests of free public transport to all (e.g., Tallin, Estonia) have been implemented and given mixed results. Cats, Susilo and Reimal [34] showed that the proportion of car users decreased by 5% following the implementation of free public transport, but that the average distance travelled by car simultaneously increased, leading to a 31% increase in total vehicle km. Hence, these interventions may not always have the desired effect. Other solutions to reduce car ownership and dependency have come to the fore in the form of market-based services. Mobility-as-a-service (MaaS) is one such concept designed similar to a flexible mobile phone account. The service combines public transport, car sharing, a rental car service, taxis and a bicycle system—all in one smartphone app, all on one invoice, with 24/7 support and bonus points for sustainable transport choices. This form of solution is currently widely discussed both by researchers and by practitioners, and has also recently been rated by experts as their top choice [35]. However, concerns have been raised about its effectiveness with respect to sustainability as it may sometimes lead to increased car use; some subscribers take the opportunity to test new cars out of curiosity, resulting in rebound effects once again [36]. However, trials of MaaS are yet in their infancy and determination of the effects will have to wait until more studies have been conducted, and followed over time. More research is indeed needed to better understand the reasons behind ours and others findings, and to determine under which conditions interventions may work, and when they may have undesired effects. The models proposed in this paper would be valuable in such assessments.

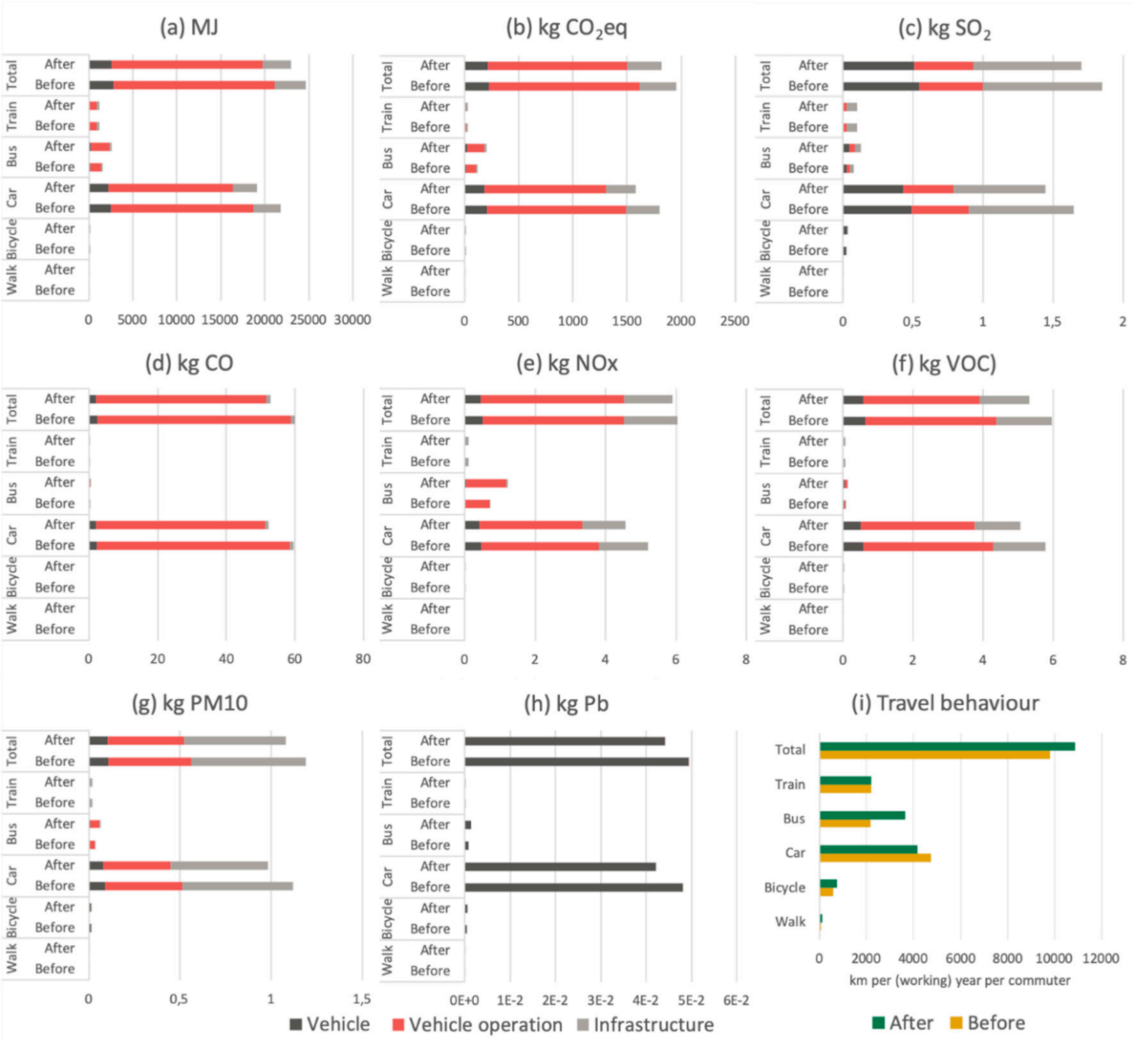

Figure 5. Environmental footprints of intervention effect, considering the commuters travel during peak hours when the vehicles have full occupancy: (**a**) energy footprint, (**b**) carbon footprint, (**c**) sulfur dioxide footprint, (**d**) carbon monoxide footprint, (**e**) nitrogen oxide footprint, (**f**) volatile organic compound footprint, (**g**) particulate matter footprint, (**h**) lead footprint and (**i**) travel behavior to different transport mode.

4.2. Data Quality of the Model

The data for the developed passenger travel model is taken from EcoInvent 2.2 database and the data from the literature [8,21–23]. Although the model is developed based on the Swedish situation in 2019 and applied to the case in the county of Värmland, the data for the most sensitive parameters (i.e., occupancy and life span of the vehicles) are taken from the literature. We investigated the possibility of getting actual data on occupancy and life expectancy from the transport authority of the county of Värmland. However, they could not provide the data due to unavailability. The results of the model and the application of the model to the intervention study were presented to the transport authority of the county of Värmland. They did not raise any concern regarding the data of the model. In addition, the model and data sensitivity were presented in a conference in sustainable transport in the county of Värmland [37].

The simulations have used data from the Swedish energy system that has a very low carbon intensity. Most of the data for vehicle and infrastructure life cycles are either international or European average (see the Supplementary Materials for details of the data sources). Thus, the model can be applied to international cases by changing the energy systems for the specific countries (e.g., changing the electricity grid mix to the specific country for trains and lighting roads).

5. Conclusions

Life cycle assessment of different transport modes shows that the car mode generally results in the largest environmental footprint (the most resource intense transport mode per person kilometer travelled), while bicycle and walk modes have much smaller environmental footprints. Travel by bus results in the second largest of the environmental footprints. The train mode gives smaller environmental footprints compared to the transport modes of bus and car. Travel by train was also demonstrated to be the most favorable transport mode for global warming potential thanks to the low carbon intensity of the Swedish electricity system. In the sensitivity analysis of the input parameters related to the life cycle inventories of the transport mode model, occupancy (i.e., people in the vehicle) was the most important parameter in influencing the environmental footprint.

A very broad general conclusion from the study is therefore to change personal travel modes to walk, bicycle and train mode as much as possible. Here, the positive health aspects of walk and bicycle mode transport should be an important aspect in the discussion in our opinion (e.g., walk and bicycle transport reducing demand for resource consuming work-out installations).

The temporary free public transport intervention reduced PKT in the car transport mode by 12%. However, it caused an increase of 67% PKT in the bus transport mode. The total environmental footprint of energy, carbon and nitrogen oxide increased after the intervention if the footprints were calculated based on the default model, which represents an average estimation for the Swedish situation in 2019. If the commuters were assumed to travel during peak hours when the buses and trains run with full occupancy, the energy, carbon and nitrogen oxide footprints decreased after the intervention. Thus, the study demonstrates how complex the discussion of different travel modes is. Therefore, even if our study advocates public transport over car transport, it shows that a very broad approach is necessary when planning and evaluating travel mode interventions. Interventions may lead to both positive (or negative) social impacts as well as changed environmental and economic outcomes. We foresee that this complexity will become increasingly important to study and evaluate in further studies.

Supplementary Materials: The following are available online at http://www.mdpi.com/2071-1050/11/24/7092/s1, Excel S1: Passenger travel model.

Author Contributions: R.S. and B.F. designed the life cycle inventories for the model. L.E.O. conducted the intervention study. R.S. developed the model, analyzed the data and wrote the manuscript. B.F. and L.E.O. contributed with comments and improvement suggestions to the manuscript.

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