Decision support for sustainable mobility policies at ULiege: A focus on daily home-to-work travels to the Sart Tilman campus

Romain Vanderbeeken[1]
Pierre Duysinx[2]

Abstract: *The solo driving is a popular commuting habit in Wallonia. Associated to an internal combustion engine vehicle, the related CO_2 emissions represent most of the total emissions among the set of transportation modes over a given community of workers. This article focuses on the fulltime workers of ULiege at the Sart Tilman campus. The federal survey on mobility and displacements (2024) provide rich information that help to build realistic modal shift scenarios. Supported by CO_2 emissions computation specific to our case study, a 55% decrease in total emissions is targeted. A discussion about a painfulness index associated to modal shifts from the solo driving is also proposed. The study results in a reduction of about 50% of the solo driving in terms of mileage in the profits of the train and the E-Bike. Several influence parameters are also emphasized, among which the minimum modal share for a given mode and the rate of electric vehicles in addition to the painfulness index.*

Keywords*:* Commuting, solo driving, transportation environmental footprint, modal shift, mobility politics, mobility survey

1. Introduction

In Belgium, the largest employers have the obligation to submit every 3 years their employees to a federal survey on their habits in home-to-work travels. The analysis of the results to the 2024 survey is aligned with the observation at the Walloon level where private cars are mainly equipped with conventional internal combustion engines (Wallonie Mobilité SPW, 2024). Additionally, the driver is generally the only person on board. In particular, 53.9% of the full-time workers at the Sart Tilman campus are used to the solo driving for their daily trips between home and the campus (Université de Liège, 2024).

The main purpose of the article is to establish a series of influence parameters aiming to assess the required level of people's acceptance to change their habits towards a more sustainable daily mobility. This study therefore addresses partial modal shift scenarios from the solo driving by focusing on full time workers at the Sart Tilman campus (academic and scientific staff, employees, etc.; students are not considered in this study). The results of the research can then be valorised as a decision support for new mobility policies at ULiege.

The article first presents the campus, the mobility options and the current commuting habits. For each main mode of transportation, the CO_2 emissions per km per passenger are then assessed to evaluate the total CO_2 emissions of the commuting journeys over one year. Based on these data, modal shift scenarios are established to significantly decrease the total CO_2 emissions. Finally, the last section concludes the article and present some perspectives.

[1] Ground Vehicle Engineering, Aerospace and Mechanical Engineering (A&M), University of Liege, Belgium. email: {Romain.Vanderbeeken@uliege.be}
[2] Ground Vehicle Engineering, Aerospace and Mechanical Engineering (A&M), University of Liege, Belgium. email: {P.Duysinx@uliege.be}

2. <u>Current commuting habits</u>

In this section, the location of the Sart Tilman is presented as well as the different options to reach it. From the answers to the federal survey, a link between the commuting distance and the transportation mode is highlighted. Afterwards, the current modal share of each mode is presented in terms of mileage. Even if the number of respondents to the survey represents only part of the community (around 40%), it is assumed that commuting habits are well captured and that classic extrapolations can be performed to the whole community.

2.1. Mobility options to reach the Sart Tilman campus

The campus is located on a hill (alt. 245 m), at 8 km at the south from the centre of Liège (alt. 60 m) as illustrated on the map in Figure 1. It is accessible by car via several national roads. It can also be reached by bus as well as by bike. In the coming months, new busway lines will replace some of the current lines while new cycling roads will be operable. Additionally, an App (*UGo*) dedicated to carpooling is made available for ULiege community. However, there are very few housings close to the campus, rendering the walk very limited. Even if there is no railway station in Sart Tilman, the combination of the train with a secondary mode of transport is fully feasible.

Based on the survey, it can be interesting to have a look at the perimeter of influence of each transport mode. The Table 1 refers the minimum and maximum single trip distances reported by the respondents at the survey for their main mode of transport between their home and the campus. To remove outliers, these values exclude the lowest 5% and highest 5% commuting distances for every mode. It can be seen that the zone of influence of the car (between 6 and 62 km) is the second largest after the one of the train. However, the minimum commuting distance for the train is much higher than of the other modes. Consequently, no overlapping arises between the bus and the train. From a detailed analysis of the surveys, train users generally come from another province while bus users mostly live in Liège city and in the neighbourhood of the city. This explains why the maximum commuting distance for the bus is 20 km.

In Table 1, it is suggested that the walk can be chosen by people up to 6 km far from the campus. The bike and the E-Bike have a very similar ring of use, with a small advantage for the E-Bike (up to 25 km against 20 km for the bike). Concerning carpooling, the data shows that the zone of influence is a bit contracted compared to the solo driving.

Figure 1 : Map of Sart Tilman and the neighbourhood at the east

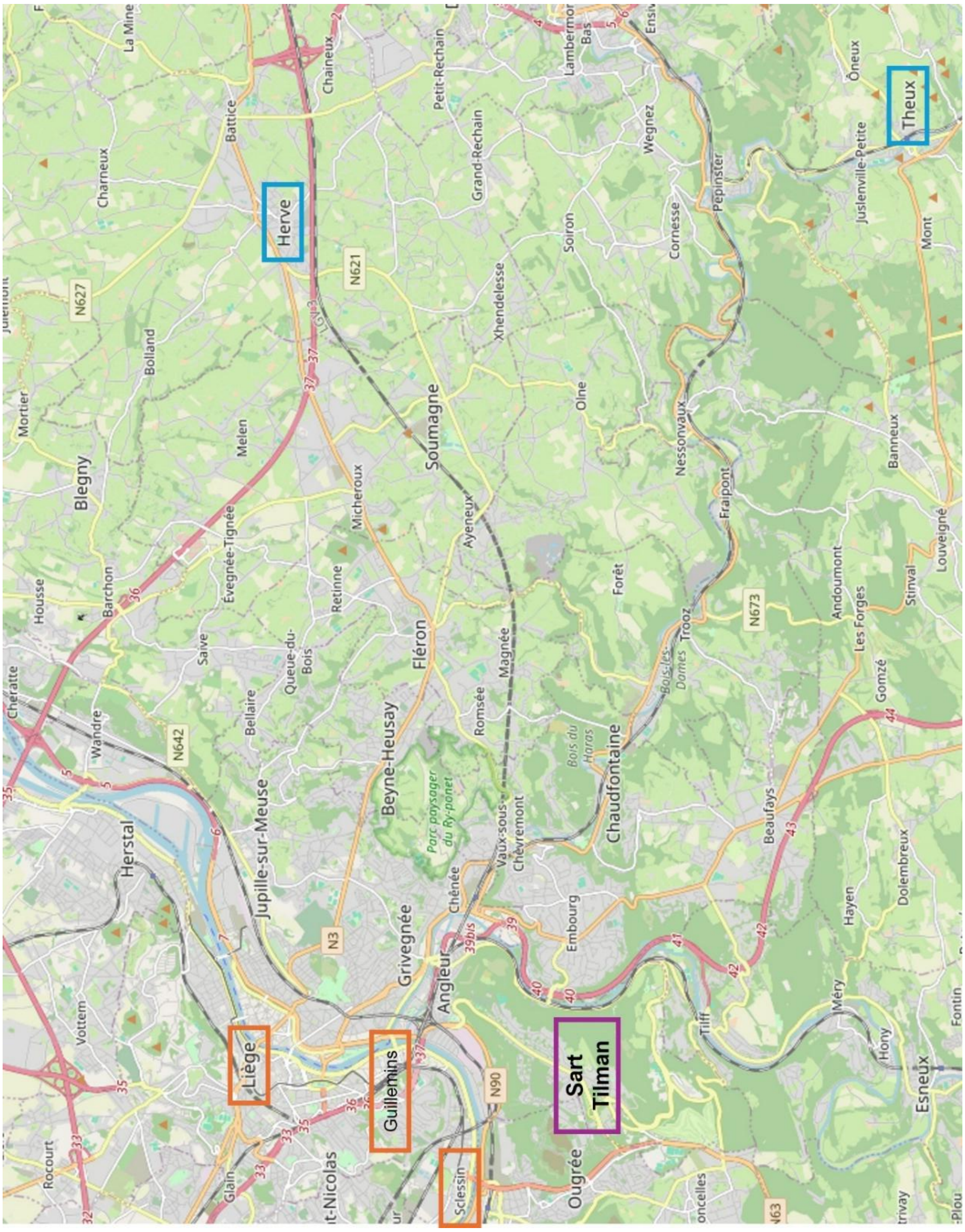


Table 1 : Min. and max. commuting distances for each main mode (single trip)

Main mode of transport	Min. commuting distance	Max. commuting distance
Solo driving	6	62
Walk	0	6
Bike	2.5	20
E-Bike	2.5	25
Bus	4	20
Carpool	4	48
Train	25	120

2.2. Current modal share

In order to focus on the yearly CO_2 emissions for each transport mean, the modal share of each mode can be studied with respect to the number of days per week that workers are present at the campus. This mainly depends on the workload (84% of people work at full time, i.e. 5 working days per week) and on the commuting distance. From the surveys, a direct link between the commuting distance and the weekly presence on site can be established. For instance, the median commuting distance of people teleworking 1 (resp. 2 and 3) day per week is 15.5 km (resp. 18 km and 32.5 km). However, 78% of workers have maximum 1 day of teleworking per week.
The Table 2 reports the modal share in terms of mileage for full time workers by presenting in the last four columns the results in function of the weekly presence at workplace. Therefore, each line specifies the modal share of a given mode for a given weekly regime. In Table 2, the car, especially in solo driving, is the dominant transport mean. For people coming 2 days per week (largest commuting distance), the modal share of the train reaches 35.8% while its modal share drops to less than 14% in the other columns (lower commuting distances). The last three lines before the *Total* line are dedicated to active modes. They represent up to 4.9% (E-Bike, 4 d/w) but are generally associated with a low commuting distance. Finally, the modal share of the bus is roughly twice the one of the E-Bike.
Although the results are presented with respect to the mileage, the trend is very similar by comparing in terms of number of people. The main difference is linked to the distance reachable by each mode. For example, the 35.8% of modal share in mileage for the train (2 d/w) thus corresponds to 15.2% of workers at campus 2 days per week. On the contrary, the E-Bike is chosen by 9.1% of people coming 4 days per week (4.9% in mileage).

Table 2 : Current modal share (full-time workers)

Modal share in terms of mileage [%]		Weekly presence at Sart Tilman campus			
		2 days/week	3 days/week	4 days/week	5 days/week
Main transport mean	Bus	6.0	3.8	4.6	9.3
	Train	35.7	13.9	11.3	6.6
	Carpooling	6.9	12.2	14.9	17.2
	Solo driving	47.3	65.6	62.4	60.4
	Bike	0.5	1.7	1.9	2.4
	E-Bike	3.6	2.8	4.9	4.0
	Walk	< 0.1	< 0.1	< 0.1	0.1
Total		**100%**	**100%**	**100%**	**100%**
Number of people		166	713	909	1526

3. CO_2 emissions computation

This section aims to quantify the share of each mode of transport in the distribution of the total CO_2 emissions originating from the daily commuting travels of the workers to the Sart Tilman campus over one year based on the federal survey.

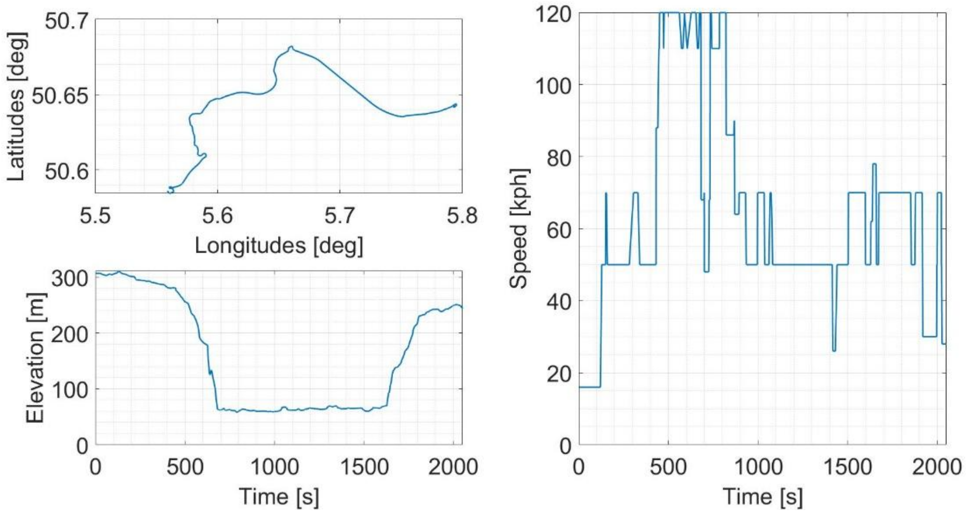
3.1. CO_2 emissions by mode of transport

In the literature, various levels of CO_2 emissions for any mode of transport are referenced. The results from the homologation of the vehicles through the WLTP[3] can be used but it appears that the emissions in real-world testing are significantly higher

[3] Worldwide Harmonised Light vehicles Test Procedure: homologation procedure constituted of a standard driving cycle assessing the fuel consumption and the pollutants and CO_2 emissions of vehicles.

(The Shift Project, 2020). The case study of this article deals with Sart Tilman campus, located on a hill as mentioned above. Therefore, it is appropriate to adapt the emissions levels to the specificities of our case study.
This is why some reference route profiles of similar distance are created for the study. In the survey, the respondents provide their zip code. Hence, it is interesting to generate various route profiles linking the campus with starting points corresponding to the center of several regions where a considerable number of people come from. The Figure 2 presents a 29.6 km route starting in Herve (northeast to Sart Tilman, Figure 1). This distance, as well as the denivelation and the type of routes, is fully representative of the mean commuting distance of people used to come by car (25 km). The route, the elevation and the speed profiles are obtained from the open-source routing library *Graphhopper* based on the *OpenStreetMap* data. Two other routes are created. They start from Villers-le-Bouillet and Theux (resp. west and southeast to Sart Tilman, Figure 1) and last 30.4 and 28 km.

Figure 2 : Route, elevation and speed profiles between Herve and Sart Tilman



By applying our own model of fuel consumption validated against the WLTP ratings to these route profiles (Vanderbeeken et. al, 2025), a scaling factor between real-world consumption and the WLTP results can be computed. Considering the sedan *Mazda 3* as well as the repartition of workers home centered in Herve, Villers-le-Bouillet and Theux, the scaling factor appears to be 1.1. Assuming gasoline cars only (< 3 % of respondents use an electric car), the specific CO_2 emissions for solo drivers is 212.2 $gCO_2eq/km/pax$ by considering 312 gCO_2eq/kWh from gasoline accounting for indirect emissions (The Shift Project, 2020). This also includes the indirect emissions of the car itself based on *Climobil* App from the LIST[4].
The energy consumption and the CO_2 emissions of the whole set of transport means investigated for the study are reported in Table 3. The energy consumption data of the modes other than the car comes from the *Shift Project* (The Shift Project, 2020). However, the CO_2 emissions of a given mode are obtained from its corresponding energy consumption and the CO_2 emissions by kWh for the fuel/electricity if any. An amount of 322 gCO2eq/kWh is considered for diesel (The Shift Project, 2020) and 110 gCO_2eq/kWh for the Belgian electricity mix (ENTSO-E, 2025). The CO_2 emissions associated with carpooling are directly obtained from the solo drivers. From the survey, it is deduced that there is a mean of 2.35 people by car amongst carpoolers.

[4] Luxembourg Institute of Science and Technology: https://climobil.lu/

For public transport, diesel buses of 160 places and trains of 300 places are considered. The rate of occupancy, strongly variable throughout the day, is set by hypothesis at 60% for the bus and 50% for the train. Compared to the car (single occupancy), the CO_2 emissions for the bus and the train correspond therefore to 5.9% and 4.7% respectively. Furthermore, the data for the train accounts for an additional contribution. Indeed, it is assumed that train commuters reach the campus by bus from Liège-Guillemins station.

In order to compare as objectively as possible the CO_2 emissions of the different transport modes, the CO_2 data associated to the active modes (bike, E-Bike and walk) account for the indirect emissions from nutrition by considering a classic diet (i.e., neither strongly meaty nor vegetarian). The electric bike is associated with larger values than the bike but remains at the same order of magnitude as the public transport. However, the walk assumes 55 gCO_2eq/km/pax due to the lower efficiency of walking compared to cycling (The Shift Project, 2020).

The last three lines in Table 3 correspond to electrified vehicles. As for the gasoline car, our own model computes the energy consumption for the *Volkswagen ID.3* (Vanderbeeken et. al, 2025). The difference with respect to the gasoline car comes from the higher efficiency of electric powertrains compared to conventional powertrains equipped with internal combustion engines. Additionally, the lower emissions of electricity compared to gasoline are advantageous for the electric car. For these reasons, electric cars are associated with 65% less CO_2 emissions than gasoline cars. The data for the electric bus suggests a similar trend, even if the CO_2 emissions per passenger for the diesel bus are already well below those of gasoline cars. Finally, light electric cars like the *Renault Twizy* are associated to half of the values of electric cars.

Table 3 : Energy consumption and CO_2 emissions of each transport mean

		kWh/100km/pax	gCO_2eq/km/pax
Main transport mean	Car (gasoline)	56.2	212.2
	Carpooling (gasoline)	23.9	90.3
	Bus (diesel)	3.6	12.5
	Train (electric)	6.0	9.9
	Bike (human)	< 0.1	12.0
	E-Bike (human, electric)	0.7	15.0
	Walk (human)	< 0.1	55.0
	Car (electric)	18.3	73.2
	Bus (electric)	1.2	2.27
	Light car (electric)	9.2	36.6

3.2. Annual CO_2 emissions

The total CO_2 emissions of the daily home-to-work travels of the workers to the Sart Tilman campus are calculated over one year by accounting for all n modes of transport:

$$\mathrm{CO_2/year} = \sum_{i=1}^{n} (\mathrm{CO_2/km/pax} \times \mathrm{km/day} \times \mathrm{days/week} \times \mathrm{weeks/year} \times n_{\mathrm{pax}})_i \quad \textbf{(1)}$$

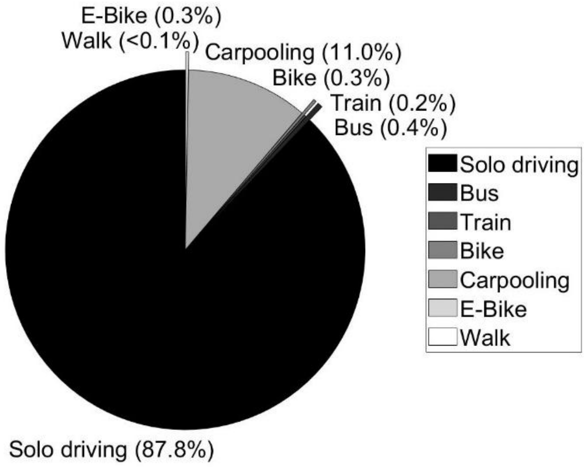
where each parameter can be described as follows:

- $\mathrm{CO_2/km/pax}$ refers to the CO_2 emissions of a given mode per km per passenger. This data can be found in Table 3.

- $\mathrm{km/day}$ corresponds to the back-and-forth mean commuting distance for a given pair of transport mode and number of days per week at the campus.
- $\mathrm{days/week}$ is the number of days per week people are physically present at the campus (2, 3, 4 or 5).
- $\mathrm{weeks/year}$ is the number of weeks over one year people are working (47 weeks by assuming for 25 days off per year).
- n_{pax} is the number of people used to mode i for a given number of days per week at the campus.

Then, in sight of studying modal shift scenarios, the CO_2 emissions can be compared in terms of each mode of transport among the first seven modes listed in Table 3 (no electrified vehicles). The Figure 3 represents the distribution of the CO_2 emissions for each mode according to Equation 1 following the surveys in 2024. It can be seen that the distribution is heavily dominated by the contribution of the solo driving (87.8%). This can be explained by a combination of factors. First, solo driving represents up to two thirds of the total mileage (Table 2). This results at the same time from a mean commuting distance higher than for the other modes (except for the train) and from a large popularity (53.9% of workers are used to solo driving). Second, the solo driving is associated to high levels of specific CO_2 emissions compared to the other mobility options (Table 3). And besides, Figure 3 indicates that carpooling represents 11% of the total emissions. Combined with the solo driving, the car contributes to more than 98% of the total emissions against 68.8% of modal share in terms of number of people. Hence, it highlights the overrepresentation of the car from a CO_2 analysis.
In Figure 3, the bus, the train and the active modes each contribute to less than 1% of the distribution. Except for the train, it can be explained similarly than for the car. Indeed, the bus and the active modes are associated to lower mean commuting distances and lower specific emissions (Table 3) with a roughly constant modal share with respect to the number of days per week at the campus. Even if the mileage of train users is significantly higher, its higher popularity can be found in people coming to the campus 2 days per week. This logically decreases the contribution of the train over a year.
In terms of absolute values, this distribution corresponds to 4078 tons of CO_2 in 2024. Since there are 3530 people working at Sart Tilman campus, it corresponds to a footprint of 1.16 tons of CO_2/year/person. As discussed above, this though hides huge variations depending on the transport mode, the commuting distance and the number of days per week at workplace.

Figure 3 : Current distribution of the total CO2 emissions by transport mean



From the analysis of the specific emissions of each mode (Table 3) and the current distribution of the total CO_2 emissions by transport mode (Figure 3), it can be interesting to investigate modal shift scenarios to decrease the annual emissions. In the next section, a combination of different transport means to shift from the solo driving is assessed. Additionally, the improvement offered by electric vehicles is also studied.

4. Modal shift scenarios

In an effort to propose modal shift scenarios as realistic as possible, several conditions need to be stated and enforced prior to solve any optimization problem. This section starts by presenting these conditions and pursues with a discussion on the painfulness associated to a given modal shift starting from the solo driving. Afterwards, a new modal share validating all the conditions is presented.

4.1. Realistic conditions for modal shift scenarios

The feasibility of a modal shift from the solo driving is influenced by an extensive number of factors. The purpose of this article is not to account for every factor but rather to present the results of modal shift scenarios by accounting for major parameters leading to realistic solutions.

A starting point to express desirable scenarios consists in accounting for the targeted evolution of the modal shares as presented in the ULiege mobility politics elaborated in 2019 (Université de Liège, 2019). The evolutions are reported in Table 4. The positive evolutions indicate a minimum targeted increase while the negative evolution (solo driving) corresponds to a minimum targeted decrease (in absolute values). In this study, these rates are applied on the mileage. The minimum increase span from 4% to 6% while the solo driving should be decreased by at least 15%. The walk is not assigned to any evolution due its limited potential in Sart Tilman (Section 2.1).

Table 4 : Targeted evolution of modal share in terms of mileage

Transport mode	Bus	Train	Carpooling	Solo driving	Bike	E-Bike	Walk
Targeted evolution	+5%	+5%	+6%	-15%	+4%	+4%	/

The evolution from the mobility politics established in 2019 are mainly based on the objective of stabilizing the supply and demand of parking facilities. Therefore, these

evolutions are completed by a constraint on the CO_2 emissions and on the energy consumption. Hence, both metrics are enforced to a decrease by 55% compared to 2024. Moreover, the current modal share of the transport modes other than the car (single occupancy) are supposed to remain at least at the current level.
Some additional constraints are set on public transport use. Since there are three main bus lines at the campus (lines 2 and 3 from Liège city and line 8 from Sclessin, Figure 1), the solo drivers who provided in the survey a zip code corresponding to a location served by one of the bus lines are placed into a group of potential new bus users. The groups are categorized in function of the number of days per week at the campus. Likewise, a group of potential new train users is constituted with the respondents who supplied a zip code corresponding to a location where there is a railway station.
Also from the survey, the Table 1 reported the typical commuting distances for each mode. This is taken into account to elaborate the modal shift scenarios to ensure realistic solutions. For instance, no solo drivers will be associated to a shift to the E-Bike for a commuting distance greater than 25 km. Obviously, only the intersection of the constraints is kept. Therefore, a solo driver living at 10 km from the campus but away from a location served by the bus lines will never be assigned to a shift to the bus.
To ensure a minimum homogeneity of solo drivers according to the number of days per week at the campus, the modal share of solo drivers whatever this parameter is set between 45 and 70% of the corresponding current modal share.
The number of workers is assumed to be constant. However, in case of varying staff size, the individual footprint can still be compared to the current value (1.16 tons of CO_2 per year, Section 3.2). No change in teleworking regime is considered here since it could lead to other significant emissions sources (Filimonau et. al, 2021).
Finally, it is supposed a fleet of 25% of electric cars (0% assumed in 2024) and 100% of electric buses (strongly helped by the busway project). Light electric vehicles, absent in the modal shares in 2024, are supposed to be potentially chosen for people living in the zone of influence of the E-Bike. Indeed, it offers a realistic alternative to the conventional car for many people such as couples with two cars or when the bus or the bike is unfeasible due to external reasons (Bigo, 2020).

4.2. Painfulness discussion of modal shift from the solo driving

The main objective of the modal shift scenarios is to minimize the painfulness of current solo drivers to shift to another transport mean. The quantification of such a painfulness index is very complicated to establish but it can therefore be subjected to a sensitivity analysis. Starting from a first reasoning specific to our case study, the values of the painfulness index associated to a given modal shift from the solo driving are reported in Table 5. All values are greater or equal to 1 to comply with the objective to minimize the painfulness. The minimum value, 1, is only set for the stand-by option (no shift). Public transport, especially the bus, generally have the advantage of the cost, but may suffer from punctuality problems or even strikes and overcrowding (especially the bus too). Therefore, a higher painfulness index is set for the bus than for the train (5 against 3). Due to organizational constraints and maybe a symbol of freedom associated to the car, the popularity of carpooling is limited despite the existence of the *UGo* carpooling App of ULiege. Hence, the same painfulness than for the bus is assumed.
Active modes offer a multitude of benefits (ecological, financial, about health and even time in congested places). In contrast, they suffer from the physical effort (especially to go to the Sart Tilman), for weather influence, the required investment or a negative safety feeling in traffic. The E-Bike offers a realistic option thanks to the assistance and the defrayment of the investment and the mileage. The walk has a very limited potential at the campus. Moreover, it is supposed that the bike is reserved for people very

familiar with cycling. Therefore, the E-Bike, the walk and the bike can be classified in an ascending order of painfulness index (Table 5).

Table 5 : Painfulness indexes

	New main transport mean						
	Bus	Train	Carpooling	Solo driving	Bike	E-Bike	Walk
Solo driving	5	3	5	1	7	3	5

4.3. Optimized modal share

Once the list of the constraints and the objective are discussed, the solution of the problem can be presented and analysed. As presented in the beginning of the article, the modal share is computed for each transportation mode by categorizing the workers with respect to their weekly presence at the campus (Table 2). The problem is solved thanks to the *MATLAB* function *intlinprog* (Mathworks, 2024). This is indeed well adapted to solve integer linear programming problems such as finding the optimal modal share distribution in terms of number of people (integers only) with linear constraints. The objective function concerns in the minimization of the total painfulness based on the indexes reported in Table 5 and verifying all the constraints as presented above.

The optimal solution is presented in Table 6 and presents the results under the same form as the current modal shares. On each line, the evolution with respect to the current status is indicated. The minimum evolution as suggested by the mobility politics in 2019 (Table 4) are set on the total users of a given mode. For example, the +5% target for the bus is thus not necessarily met for each category of weekly presence at the campus. Among the columns of solo drivers, the optimized modal share suggests a very constant decrease while the constraints were limiting its share between 45% and 70% of the current status. This indeed hinders an overrepresentation of the solo driving for people coming 2 days per week at the campus (for who the CO_2 emissions over the year is obviously much lower than for the other categories for the same mileage).

It can be observed that the global trend shows a major modal shift to the carpooling (2 days/week), to the bus (5 days/week), to the train (3, 4 and 5 days/week) and the E-Bike whatever the category. The analysis can be mainly built based on the new potential modes for a given commuting distance and on the painfulness indexes. Indeed, the E-Bike is fostered by its low painfulness index compared to the concurrent modes in the same zone of influence (the bus and the bike, Table 1). Its modal share gets even higher than the one of the bus. The bike suffers from the big difference in painfulness compared to the E-Bike. Concerning the bus, the constraint according to which the zip code of the respondents must correspond to a bus line already limits the number of potential bus users. However, a second painfulness index should be set if the use of a second bus line were considered.

The train is favoured due to its low painfulness index and low specific CO_2 emissions, having a big impact on the -55% of CO_2 emissions constraint for people coming 5 days per week and/or with a long commuting distance. Since the results are presented in terms of mileage, the modal share of the train in terms of number of people would nonetheless be lower.

Concerning the carpooling, the results just correspond to the constraint of +6% total increase. As for the bike, this can be explained by its relatively high painfulness index. Additionally, the typical commuting distances of car-poolers also explain the phenomenon. Indeed, the main modal shift is either to the E-Bike (small commuting distance) or to the train (high commuting distance).

Finally, it is also interesting to analyse the results compared to the maximum potential of new users of each mode. The main observation result from the optimal modal share of the bus (5 days/week) and of the train (4 and 5 days/week) where the modal share corresponds to a number of people very close to the maximum capacity (> 90 %). Even if the increase in modal share of the E-Bike is notable, it corresponds to rates lower than 80% among possible users.

Table 6 : Modal share according to modal shift scenario

Modal share in terms of mileage [%]		Weekly presence at Sart Tilman campus			
		2 d/week	3 d/week	4 d/week	5 d/week
Main transport mean	Bus	6.0 (+0%)	3.8 (+0%)	5.0 (+8.7%)	26.7 (+187%)
	Train	35.8 (+0.3%)	19.9 (+43.2%)	28.3 (+150%)	20.5 (+211%)
	Carpooling	20.1 (+191%)	12.2 (+0%)	14.9 (0%)	17.2 (+0%)
	Solo driving	22.2 (-53.1%)	29.6 (-54.9%)	28.1 (-55.0%)	27.3 (-54.8%)
	Bike	0.5 (+0%)	1.7 (+0%)	1.9 (+0%)	2.6 (+8.3%)
	E-Bike	15.4 (+328%)	32.8 (+1071%)	21.8 (+347%)	5.6 (+40%)
	Walk	< 0.1 (+0%)	< 0.1 (+0%)	< 0.1 (+0%)	0.1 (+0%)
Total		**100%**	**100%**	**100%**	**100%**
Number of people		166	713	909	1526

5. Conclusions and perspectives

This article tackles the solo driving phenomenon, generally associated to internal combustion engine vehicles, among full time workers at the Sart Tilman campus of the University of Liège. The analysis of the federal survey on mobility and displacements submitted in 2024 to the whole community highlights commuting distances rendering it challenging for active modes (bike, E-Bike, walk). Three bus lines reaching the campus offer an alternative to the solo driving for people living in the city. However, people living out of the city mainly prefer the car, especially the solo driving.

In this study, a quantification method of the total CO_2 emissions from the daily home-to-work travels is proposed. For each main transport mean, the specific energy consumption is assessed either from an own model or from data in the literature. These are then converted into CO_2 emissions. Therefore, it allows to determine the relative share of each mode in the total emissions. Given that the share of the solo driving is 87.8% while its modal share in terms of number of people reaches 53.9%, the underlying overrepresentation suggests to propose modal shift scenarios. By fixing an objective of a 55% decrease in CO_2 emissions, a new modal share is proposed and emphasizes a shift mainly to the train and the E-Bike, but also to the carpooling and the bus.

Several influence parameters are also established. The painfulness index associated to each modal shift from the solo driving has a central place in the present study. In addition, the minimum modal share of each mode and the rate of electric vehicles are other sensible parameters.

In future work, the authors plan to deepen the sensitivity analysis of the optimized modal shares with respect to these influence parameters. The improvement potentially offered by the teleworking will also be investigated. Finally, the extension of our own model of energy consumption for public transportation, a variety of vehicle models and a more detailed mapping of the route profiles can increase the precision of the study and will be performed in a next paper.

Bibliography

Bigo, A. (2020). *Les transports face au défi de la transition énergétique. Explorations entre passé et avenir, technologie et sobriété, accélération et ralentissement.* Ecole Doctorale de l'Institut Polytechnique de Paris.

ENTSO-E. (2025). *Aggregated emissions for 2024 (Belgium).* https://www.nowtricity.com/country/belgium/

Filimonau, V., Archer, D., Bellamy, L., Smith, N., & Wintrip, R. (2021). The carbon footprint of a UK University during the COVID-19 lockdown. *Science of The Total Environment*, *756*. https://doi.org/10.1016/j.scitotenv.2020.143964

Mathworks. (2024). *intlinprog.* https://nl.mathworks.com/help/optim/ug/intlinprog.html

The Shift Project. (2020). *Étude comparative de l'impact carbone de l'offre de véhicules.* https://theshiftproject.org/panorama-offre-vehicules-impact-carbone-technologie/

Université de Liège. (2024). *Résultats de l'enquête de mobilité et déplacements menée au sein de l'université de liège en 2024*. https://www.durable.uliege.be/cms/c_20352620/fr/decouvrez-les-resultats-de-l-enquete-de-mobilite-realisee-a-l-uliege-en-2024

Université de Liège. (2019). Politique de mobilité ULiège. Stratégie et plan d'actions. https://www.durable.uliege.be/upload/docs/application/pdf/2024-09/mob.politique_mobilite_-_note_dec2019.pdf

Vanderbeeken, R., Duysinx, P., & Toussaint, Y. (2025). Addressing Range Anxiety in Electric Vehicles with Physics-Based Drivetrain Models and an Appropriate Charging Strategy. In A. Chiru & D. Covaciu (Eds.), *CONAT 2024 International Congress of Automotive and Transport Engineering* (pp. 28–39). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-77627-4_3

Wallonie Mobilité SPW. (2024). *Tableau de bord de la mobilité 2024.* https://mobilite.wallonie.be/home/politiques-de-mobilite/politique-de-mobilite-regionale-wallonne/tableau-de-bord-de-la-mobilite.html