Evaluation of the potential of classic and electric bicycle commuting as an impetus for the transition towards environmentally sustainable cities: A case study of the university campuses in Liege, Belgium

Peer-reviewed author version

Nematchoua, ModesteKameni; Deuse, Caroline; COOLS, Mario & Reiter, Sigrid (2020) Evaluation of the potential of classic and electric bicycle commuting as an impetus for the transition towards environmentally sustainable cities: A case study of the university campuses in Liege, Belgium. In: RENEWABLE & SUSTAINABLE ENERGY REVIEWS, 119 (Art N° 109544).

DOI: 10.1016/j.rser.2019.109544
Handle: http://hdl.handle.net/1942/30769

Evaluation of the potential of classic and electric bicycle commuting as an impetus for the transition towards environmentally sustainable cities: a case study of the university campuses in Liege, Belgium

ModesteKameniNematchoua[a,b,*], Caroline Deuse[b], Mario Cools[b,c,d], Sigrid Reiter[b]

[a]Beneficiary of an AXA Research Fund,Postdoctoral Grant, Research Leaders Fellowships, AXA SA, 25 Avenue Matignon, 75008 Paris, France
[b]University of Liège, Urban and Environmental Engineering Department, Local Environment Management & Analysis (LEMA), Allée de la Découverte9, Quartier Polytech 1, BE-4000 Liège, Belgium
[c]KULeuven Campus Brussels, Department of Informatics, Simulation and ModelingWarmoesberg 26, BE-1000 Brussels, Belgium
[d]Hasselt University, Faculty of Business Economics, AgoralaanGebouw D, BE-3590 Diepenbeek, Belgium

[*]Corresponding author. Tel.:+3243669869;Email address: mkameni@uliege.be (M.K. Nematchoua)

Abstract

To address the negative effects of car use, conventional and electric bicyclesare often proposed as environment-friendlyalternatives. The aim of this research is to identify the prospects of a modal shift towards conventional and electric bicycles based on a case study analysing the mobility generated by the three main campuses of the University of Liège in Belgium. In the theoretical part of this paper, the known factors and strategies that affect most of the bicycle use in Europe are summarised and the need for a deeper understanding of the elements that promote a modal shift from bus and car users to the use of electric bicycles is highlighted. Consequently, the results of a survey conducted among the university population of the University of Liège(students, PhD students, and staff members;including 1496 questionnaire responses)are presented and analysed in detail. The Net Promoter Score (NPS), as an indicator of the user satisfaction, confirms that the bicycle has the best NPS compared with the main modes of transport (car and bus) and that the electric bicyclehas agreater NPS than the conventional bicycle. The importance of many factors affecting the use of cycling is lower if we consider the electric bicycleinstead of the conventional bicycle.Consideringthe current travel patterns in terms of the distances travelled, the potential for the use of conventional bicycles only reaches 23% of the university users, whereasthat of electric bicycles reaches 70%. In the pursuit of a modal report, the most imminent factor is the development of safe bike paths, where a potential increase in the bicycle use is acknowledged by 74% of the students, 62% of the staff members, 62% of the car users, and 82% of the bus users.Finally, because the lack of safe cycle lanes remains the major obstacle with respect to the use of both bicycle types, the development and/or improvement of a comfortable and secure infrastructure for cyclists within a radius of 12 km from the main school and work places, especially in the main residential and commercial areas, should be prioritised to promote the use of both types of bicycles.

Keywords: Europe, electric bicycle, e-bike, bike path, urban, user satisfaction

1. Introduction

The increasing use of private cars hasresulted inseriousenvironmental, social, and economic repercussions[1]. The IEA's 2009 report [2] stated that, unlike other sectors (residential, commercial, or industrial) with relatively diverse energy sources, the transport sector relies almost exclusively on fossil fuels: oil accounts for 95% of the energy used for transportation worldwide. The transport sector is responsible for 28% of the world's CO_2 emissions (this number increases to 30% if we only consider OECD countries) and 74% of these emissions stemfrom road transport [3]. In the European Union, 26% of the greenhouse gas emissions from private households were due to transport in 2007 [4-5]. In addition, in the last decade, the greenhouse gas emissions and energy demand in the transportation sector have increased faster than that of any other sector. Traffic congestion increased worldwide by 13% between 2008 and 2015.Other harmful consequences of the individual car use include road accidents [3], health problems related to pollution, noise emissions and lack of physical activity of the passengers [6, 7], generation of social inequalities [8], and excessive consumption of public spaces for its use and parking [9].

New solutions aiming at ecological mobility, ensuring socialinclusivity,and promoting the economy must be developed [8].Various strategies exist to trigger a sustainable mobility transition [10]: (*i*) improvement users' health and public spaces:favour active modes of transportation, such as walking and cycling,but also, to a lesser extent, collective modes of transport (bus, train, or carpooling); (*ii*) reduction ofthe pollution and dependence on fossil fuels: use of renewable energies; and (*iii*) reduction of the length of journeys:reasonably strengthen the densification of built environments.

The classic bicycleis a 'green' mode of transport, which, apart from its production, does not use energy, produce emissions,nor cause air pollution. In 2015, Cole-Hunter et al. [11] asserted that a transition from the car to the bicycle can help to significantly reduce the environmental and economic impacts of transportation, congestion in cities, demand for parking, and dependence on oil.According to Heran [12], a parking space for cars contains room to park eight bicycles and the construction of parking and road infrastructures is ~50 times cheaper for bicycles than for cars. Currently, the electric bicycle seems to become a new mode of intermediate transport, between the conventional bike and motorcycle or car. Among all motorised modes of transportation, the electric bike is the most energy-efficient and allows the use of renewable energy.

Universities often are among the largest employers in cities [13]. As a result, universities often implement strategies to reduce the dependencyon private cars and increase the use of sustainable modes of transport [14]. Moreover, universities already seem to be favourable environments for the use of alternative transport modes. According to a study carried out in 2013 in more than one hundred European cities by Santos et al. [15], a greater proportion of students in a city is indeed associated with greater modal shares of public transport, walking, and cycling. Furthermore, an extremely important, but often neglected, aspect for choosing universities as case studies on this topic is the potential to affect the mobility habits and environmental awareness that students develop over the long term. Many university students will occupy important positions in public authorities, companies, and other organisations and could have a significant influence on the establishment of more sustainable mobility. The same is true for university staff members, many of whom are already influential members of the communitywho can help cities in implementing cycling-oriented policies [15].

This paper aims to identify and evaluate strategies to improve the potential of classic and electric bicycle commuting based on a case study including the three main campuses of the University of Liège, which are located downtown and in the outskirts of the city of Liège in Belgium.In this work, the prospects of a modal shift towards conventional and electric bicycles used for home-to-work and home-to-school trips based on data for the University of Liège are analysed.Theliterature on conventional and electric bicycle commuting is reviewed in Section 2. The case study and research methodology are presented in Section 3 based on a quantitative survey including many students, PhD students, and staff members. Thediscussion of the results of the survey is provided in Section 4 and the main conclusions are highlighted in Section 5.

The main objective of this paper is to evaluate the potential of classic and electric bicycle use. Therefore, the following three research questions are addressed in this paper:

- What is the user satisfaction associated with electric bike use compared with conventional bike use and other modes of transportation?
- What are the main barriers with respect to the use of electric bicycles? Are they identical to those related to conventional bicycles?
- What are the conditions fora modal shift towards conventional or electric bicyclesfor car and public transit users?

2. Literature on conventional and electric cycling

Bicycles are often considered as environment-friendly alternatives to address the negative effects of car use but remain underutilised in many European cities. In the European Union, only 1% of the passenger kilometres are realised by bicycle, whereas73% of the kilometres are travelled by car [8]. Among the barriers with respect to cycling, the travel distance and relief are mostly cited.Increasing the area reserved for bike paths seems to be an important incentive. The literature extensively discusses the benefits and barriers of cycling [11,12]including personal and social [16-19] as well as environmental determinants [11, 15,20-27].Furthermore, several studiesfocused on bicyclepromotion methods [18, 23, 26, 28].

An important evolution in terms of the benefits and barriers ofcycling concerns the development of electric bicycles. Over the last twenty years, the production rate of electric bicycles has considerably increased [29,30]. The electric bicyclehas a better energy performance and emits less greenhouse gases[34-35, 56] than all other motorised transport modes. Consistent with the classic bicycle, the electric bicycle manages to address a series of problems caused by cars. For example, e-bikes can contribute as an active transportation mode to meet health-required physical activity guidelines [35-37]. However, fewstudies focused on the limitations with respect to the use of electric bicycles or e-bike promotion strategies in European cities. Furthermore, these studies are based on the motives of e-bike owners in Europe, which are predominantly people aged 50 years or older [37, 38].

Based on a literature review (including studies in Austria, France, Germany, the Netherlands, Norway, Sweden, Italy, and the UK) by Carins et al. [39], a significant proportion of the mileage travelled with an e-bike, varying from 35% to 76% according to the different studies, will be a replacement for car mileage. However, the potential of commuting with a classicor electric bicycleremains mainly linked to short trips. Only people living within a radius of ~8 km from their workplace are likely to travel using a classic bicycle [28, 39], with a greater potential for short distances,or electric bicycle, with trips that on average are 1.5 times longer than conventional cycling trips[34,38,39].

In terms of annual costs (including maintenance and depreciation of the equipment),the cost of an electric bicyclein Belgium is ‘only’approximately twice the cost of a conventional bicycleor the bus, and isapproximately ten times cheaper than the car[43-45].If the user can benefit from a bicycle allowance (0.21 €/km), a return journey of 16 km made 4 days a week and 10 months per year, fully compensates the costof an electric bicycle(allowanceof 540 €/year), whereasthe kilometres that are not travelled by car account for savings of 225 €/year on fuel [45].

Concerning the modal share of cycling as the main mode of transport, the European Cyclists’ Federation (ECF) reported an average share of 8% of all trips realised by bicycle for the EU-27 in 2014, varying from 0% in Malta to 23% in Denmark and 36% in the Netherlands[40]. At the local level, the share of cycling can be as high as 60%, for example, in the Dutch city Groningen. In this survey, Belgium is at the sixth place, with a modal bicycle share of 13%. Based on a detailed survey on the modal share in Belgium with respect to home-to-work trips, 9.5% of the Belgian population goes to work by bicycle [41].

Lovelace et al. [56] reviewed existing cycling propensity models and developed the 'Propensity to Cycle Tool', which can be used for the planning and prioritisationof cycling investments in the UK. Goodman et al. [61] applied this method to 'travel to school' data in the UK and assessed thehealth and carbon benefits based on nationwide scenarios of cycling uptake. Note that if the EU level of the cycling share would reach the Danish 2000 levelby 2020, between 55 and 120 million tonnes of CO_2e could be saved per year, representing 57% to 125% of the target reduction set for the transport sector (10% by 2020 compared with the 2005 levels) [42].

Women and men were found to cycle to the same extent in Europe, that is, 8% [40]. However, this ratio significantly varies in lower-cycling European countries. For example, in the UK, the ratiois approximately 3:1 in favour of men [56].Aldred et al. [57] systematically reviewedthe gender differences with respect to cycling. For other studies on this topic, please review references28 and 58–60.In European cities, different sources of potential funding are used for the creation of new cycle paths and their maintenance such as public spending (Netherlands), public/private partnerships (Switzerland), National Lottery funding (UK), or paid car parks with profits being transferred to the development of bicycle lanes (England) [8]. Based on European examples [40], Table 1provides suggestions of the minimum aggregated investment level per capita per year in safe cycling infrastructure and promotional measures of cycling that are needed to maintain or reach the modal split levels indicated. Table 1 shows that the use of the bicycle willsignificantly increase if the public expenditure is large and regular; however, if it is below €10 per year per inhabitant, no significant change should be expected.

Table 1:Minimum aggregated investment level per capita per year in cycling infrastructure and promotion needed to maintain or increase the bicycle modal share in Europe [40]

Category/Modal share	Maintaining the existing bicycle modal share	Increasing the bicycle modal share
Starter (≤10%)	5 €	10 €
Climber (10%–25%)	10 €	15–25 €
Champion (>25%)	25 €	30 €

3. Methodology

To identify and evaluate strategies for the improvement of the potential of classic and electric bicycle commuting, a large-scale survey was carried out among the users of the three main campuses of the University of Liège (ULiège), which are located downtown and in the outskirts of the city of Liège in Belgium. This large-scale survey provides a detailed view on commuting habits and mobility opinions of many campus users including students, PhD students, and staff members. Thanks to many respondents, the results can be differentiated according to different profiles such as the status (student, doctoral student, or staff member), area of the campus mainly attended, or modes of transport used. The analysis of these different subsamples will allow us to discuss the survey results in more detail and will improve our knowledge with respect to the potential of electric bicycle commuting.

Based on the comparison with other surveys concerning the mobility of the ULiège population, no survey primarily focused on cycling and even less on the use of electric bicycles. The survey was established based on an extended literature review and a more general survey on the‘student mobility at the University of Liege’ conducted in 2014 [43]. The results of this survey helped to guide the questions and focus of our research. Furthermore, our results were compared with the results of previous mobility surveys concerning the ULiège [43,44] and Belgium [41,45]to identify the possible bias and/or validate the consistency of our results.

Mostly closed-format questions were implemented in the survey. To minimise the risk of bias introduced by predefined answer categories, the proposed answer sets were intended to be complete and nuanced and provide a choice of ‘other’, ‘no opinion’, or ‘do not know’ responses when necessary.

3.1 Studied campuses

Belgium is a federal state comprising three regions: the Walloon Region (Wallonia) in the south, the Flemish Region (Flanders) in the north, and the Brussels Capital Region (BrusselsCapital). Liege is a city in the southern part of the country and the economic capital of Wallonia. Liege is characterised by a temperate climate, acceptable for outdoor activities throughout the year, even if the most favourable period includes the end of spring, summer, and beginning of autumn.

In 2014, 9.5% of the Belgian population went to work by bicycle, but significant regional differences were reported: in Flanders, 14.9% of the commuting trips were realised by bicycle, whereas only 1.5% of the commuting trips were performed by bicycle in Wallonia. In contrast, the overall share of the private car for commuting trips was 67% in Belgium, increasing to 82% for Walloon workers [41]. These results are consistent with the modal shares of commuting previously calculatedbased on the BELDAM survey [45] from 2010 containing information about all trips of the entire Belgian population. Thesignificant difference in the bicycle use between the northern and southern parts of the country can be partly explained by the more hilly terrain in the south compared with the predominantly flat territory in the north as well as by the higher funds allocated to pro-bike policies and the much higher quality of the bicycle infrastructure in the north. The potential of an increase in the

Belgian cycling share (including conventional and electric bicycles) remains significant given that 78% of all trips in Belgium are shorter than 15 km [45].

Figure 1. Topographic map of the city of Liège and its surroundings [53].

In Wallonia, investments in the cycling infrastructure and promotion more than doubled in 2011–2012 compared with the previous decade, reaching a 4.48 € investment level per capita per year for cycling. However, these investments are still significantly lower than those made in the Flemish region (a 17.6 € investment level per capita per year in cycling between 2010 and 2014), which in turn are significantly lower than those achieved in the Netherlands (a ~24 € investment level per capita per year for cycling in 2010) [46].Thus, there is a link betweenthe modal share percentages dedicated to cycling and the investments made at the regional level in quality cycling infrastructure.

The main campuses of the University of Liege in Wallonia were chosen as study locations.The ULiège, including its university hospital centre, is the largest employer in Liege. The city is the largest city in Wallonia and the third largest urban agglomeration in Belgium, with 200,000 inhabitants. The University alone hosts ~29,000 people including more than 20,000 students. In Liège, the university campuses are in the city centre and approximatelyten kilometres south of the city centre (SartTilman campus). The SartTilman campus is itself divided into two subcampuses, thatarethe northern and southern zones (called ST North and ST South, respectively). These three campuses, which were considered in our study, are the main campuses of the University of Liège (see Figure 2). Two small additional campuses are linked to the University of Liège, but they were not considered in this studybecause of their locations (Gembloux and Arlon) far from the main campuses.

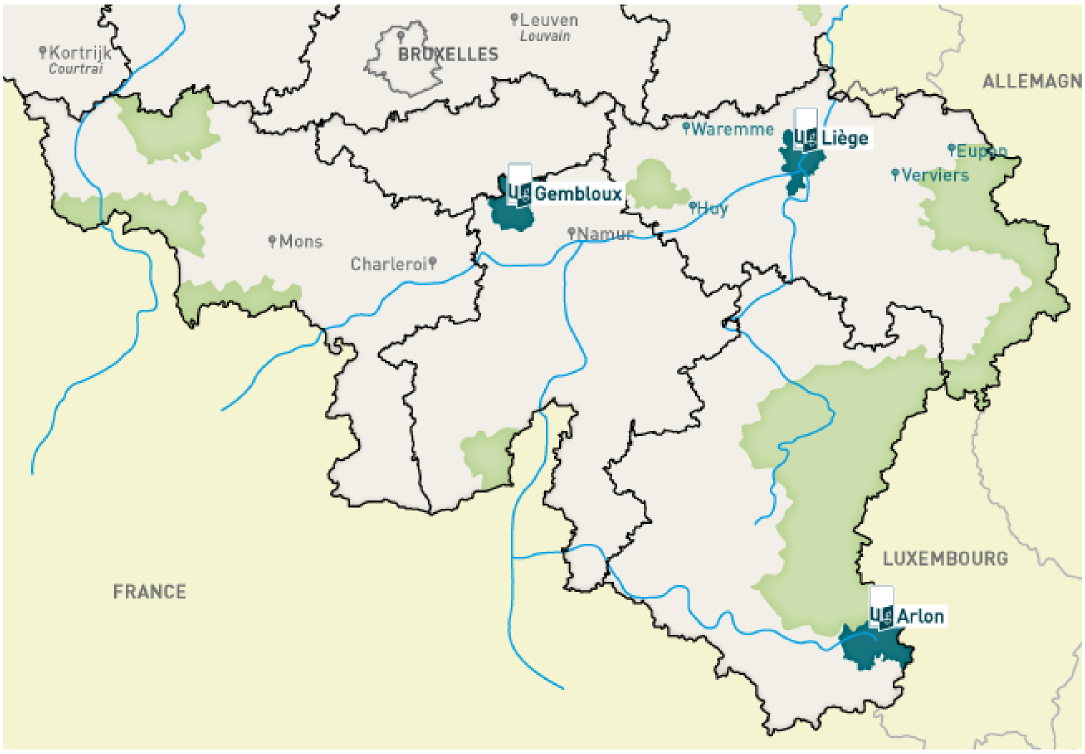

Figure 2: Location of the University of Liège [54].

The downtown campus is 2.5 km long and completely integrated into the urban environment of the centre of Liège. The northern and southern zones of the SartTilman campus each extend over ~2 km. The architectural and urban design of the SartTilmancampus aimed to be in harmony with nature, preserving the wooded areas and providing many walking paths in protected natural areas. However, the construction of the SartTilman campus in the 1960s resulted in a low-density campus, mainly designed for cars, with few cycling links between the ST campuses and city centre. From a topographical point of view, the city of Liege is characterised by hilly terrain. The downtown campus is in the Meuse Valley, whereasthe SartTilman Estate is 200 m higher on the Meuse Plateau. There are considerable slopes on both sides of the Meuse, a short distance away from the valley.

In the urban area of Liege, home-to-school travel consumes less energy than home-to-work travel because the distances from home to school are shorter than the distances from home to work and the use of public transport is higher for home-to-school travel than for home-to-work travel[47].Analyses of school commuting in Wallonia showed that the concentration of tertiary educational institutions in and around urban centres leads to higher energy consumption, greater travel distances, and less active commuting related to universities and higher schools compared with nursery and primary schools, which are better distributed across the region [48].

3.2 **Questionnaire**

The questionnaire was conducted online using Qualtrics. The pre-testing of the survey was carried out between 29 February and 22 March 2016. During this period, different stakeholders were contacted to ensure that the results are not only useful to the ULiège but also to the City of Liège and various cycling organisations (e.g.GRACQ, Pro Velo). The questionnaire was also pre-tested to verify that all questions are clear, the answer choice setsare complete, and the length of the questionnaire is acceptable. Based on the results of the pre-test, the questionnaire was modified.The final questionnaire considered all revisions that were required based on the feedback from the pilot survey.

The final questionnaire was sent by the university services by email to all ULiège students, doctoral students, and staff members, accounting for a population of ~29,000 people. It was available for a little over three weeks, from 24 March to 17 April 2016. It is divided into different parts:

1. The first set of questions concerns the respondents' profile. The questions in this section are usedto evaluate the representativeness of the sample and to identify whether the responses in the rest of the questionnaire vary according to the individuals' profiles. The questions about the address and campus that is frequented the most by the respondent are used to calculate the corresponding distances and altitude differences of residence–university journeys to assess the real potential of the bicycle use.
2. The second set of questions deals with the modes of transportation in general. The purpose of these questions is to study the travel habits of the respondents (in particular the extent to which the bicycle is currently used as a mode of transportation) and to identify whether the responses in the rest of the questionnaire vary according to the current transportation behaviour of the individuals. Furthermore, questions are asked about the satisfaction with respect to the used transport modes.
3. The next part focuses on issues concerning the bicycle. The first set of questions concerns the perception of conventional and electric bicycles. Based onthese questions, we can identify to what extent the bicycle is viewed as a valid mode of transport and accessible, who the users of conventional and electric bikes are, and to which extend the characteristics of the electric bike are known.

4. The next two sections deal with the perception of the factors influencing the use of bikes and electricbicycles. The purpose of these questions is to identify the factors and to assess the differences that may exist between the perception of certain factors (e.g. distance, travel time, cost, climatic conditions)with respect to both types of bicycles. Furthermore, the respondents are asked why they do not use or not more often use the bicycle as a mode of transportation.
5. Finally, the last section is intended to understand the conditions that are necessary for a modal shift towards an increased level of bicycle use.

3.3Cleaning and processing data

The geographic information was processed using the ‘My Maps’ application of Google Mapsto calculate the cycling distance between homes (addresses provided in the questionnaire) and the central point of the selected campus. Figure 3 shows the main cycle path connecting the centre of Liège andnorthernSartTilman campus. The quality of the cycle path represented in the figure is based on an *in situ* evaluation of the main cycle paths by the authors, accompanied by an interview with three cyclists accustomed to each trip to verify the accuracy of our observations. This evaluation was also used to validatethe kilometres and cumulative altitude differences calculated by Google Maps.

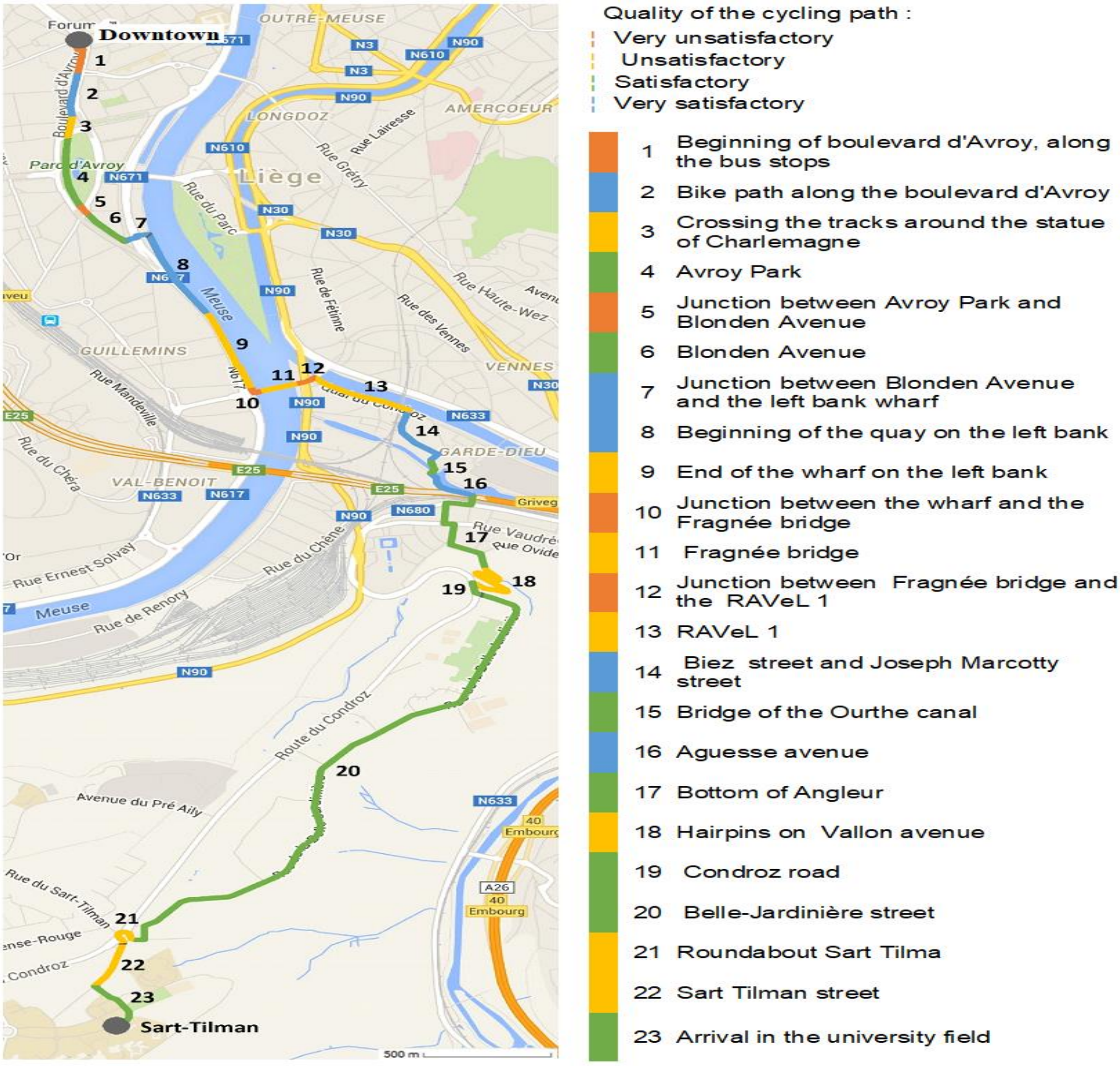

Figure3. Main cycle path between the city centre and SartTilmancampus and evaluation of thequality of the whole cycle path.

A total of 1,496 responses to the questionnaire were recorded, representing a response rate of 5.2% of the 29,000 respondents; 19% of the answered questionnaires (287 responses) were incomplete (questionnaires were partially answered) and were not considered in the analysis. Before starting the analysis, the data werecleaned. The response time to the questionnaire averaged ~15 min, with several dozens of questionnaires completed in 5 or 6 min; particular attention was paid to the consistency of the answers, but nothing suspicious was detected. During the analysis, several completed questionnaires were deleted, either because the respondent was not part of the intended audience (for instance the respondent's main activity location was none of the three Liège campuses), because of inconsistent responses, or because the comments indicated a lack of seriousness. After the data were cleaned, 1206 responses remained, representing a net response rate of 4.2%. All answers to the questions providing ‘Other’ as answer choice and asking for clarification were read and possibly reclassified into appropriate categories.

For questions requiring an estimate (e.g. distances, travel times), all null values and extreme values compared with others were suppressed. The residence address question required significant processing. Among the 1206 respondents, 946 (78%) provided a specific address (municipality, postal code, street, and possibly number), 246 respondents provided only the postal code or municipality, and the rest did not answer the question. Researchersdecided not to use the information of the postal code when the address was not sufficiently precise; however, the questionnaires of these respondents wereused for all other statistics.

Figure 4 shows the distance decay curve of the bike and e-bike uses based on our survey. Figure 5 presents the same curve drawn by the authorsfor the results of the national BELDAMsurvey [45].

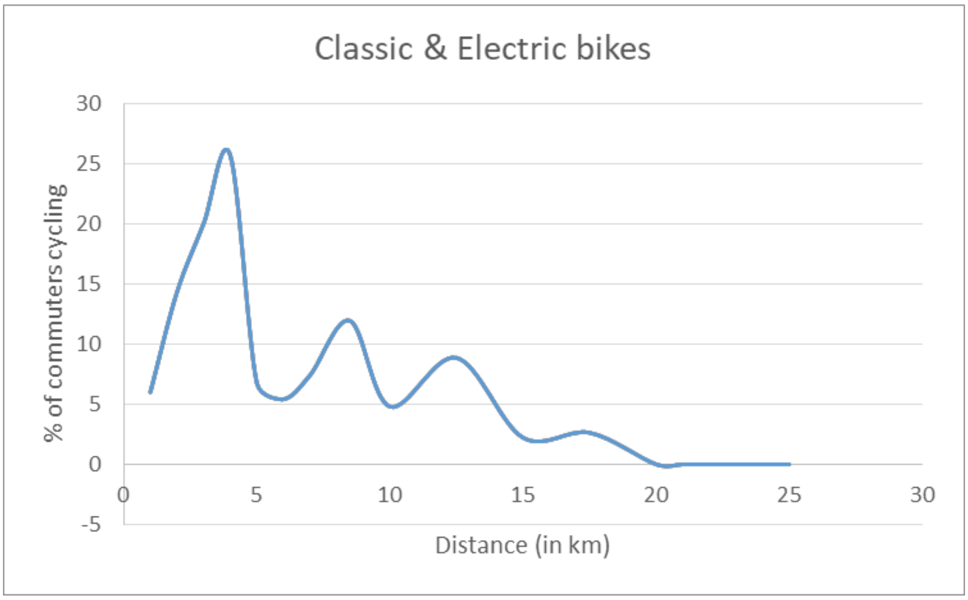

Figure 4.Percentage distribution of the distances travelled by commuters by cycling using classic and electric bikesbased on our survey.

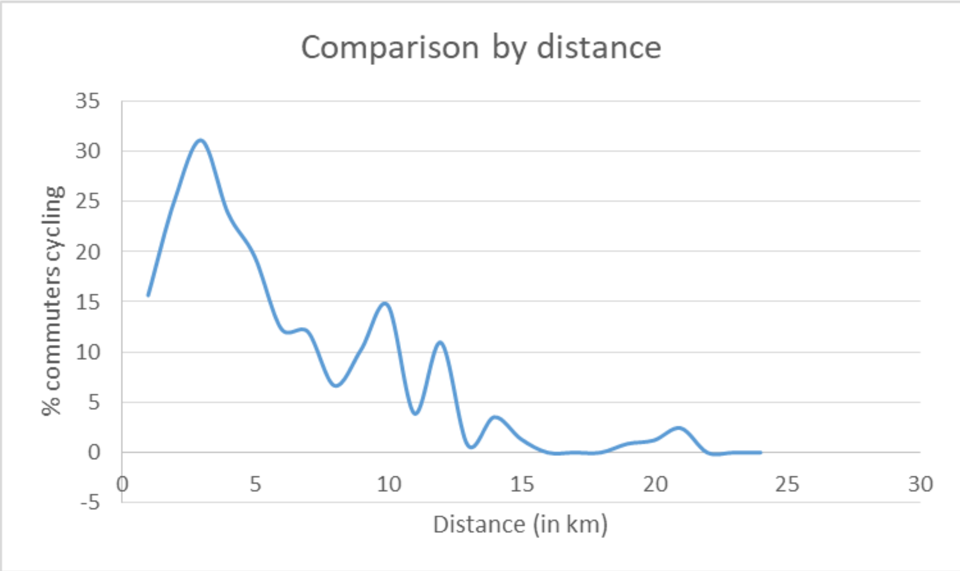

Figure 5.Percentage distribution of the distances travelled by commutersby cycling using classic and electric bikes based onthe national BELDAM survey.

3.4 Sample of respondents

Table 2 lists the main ULiège statistics to which we compare our sample of respondents. Based on this table, students are underrepresented, whereasPHD students, staff members, and women are overrepresented.

Table 2: Comparison between the total population of the University of Liège and the sample.

		Population ULiège		Sample of respondents		Response rate (%)
Total		29,029	100%	1206	100%	4.2%
Status	Student	20,455	70%	689	57%	3.4%
	PHD student	1,728	6%	126	10%	7.3%
	Staff	6,846	24%	391	32%	5.7%
Sex	Male	13,334	46%	501	42%	3.8%
	Female	15,695	54%	705	58%	4.5%

In addition to the status and gender of the sample, one must consider the fact that a survey attracts more people that are feeling concerned about a subject. A questionnaire on cycle mobility tends to mobilise mainly two types of people: people with claims or complaints about it and people practicing cycling or in favour of its practice. In our case, cyclists are overrepresented (see Section 4.2). When we think that this bias could have had an influence on the results of some questions, we will report and explain it.

4. Results and discussion

4.1 Cycling potential based on distances travelled and cumulative altitudedifferences

The addresses provided by the respondents were used to tabulate various metrics such asthe exact distance between the place of residence and the main visited campus, difference in altitude, travel time, and main roads taken. The spatial spread of the home locations can also be calculated, which in our survey indicated that a higher density of ULiège members resided in the city centre of Liège, especially when home addresses of students were investigated.

Given the topography of the urban area of Liège, the difference in the altitude must be considered in addition to the travel distance. Figure 6 shows the cumulative altitude differences for the distances most likely to be travelled by bike (1 to 12 km).These cumulative altitude differences were calculated using the ‘My Maps’ application of Google Maps by selecting the proposed route for bicycles and adding the uphill and downhill altitude differences.Few people living less than 4 km away from the ULiègeexperience a significant cumulative altitude difference on their route to the university. However, mostof the people who have to travel more than 4 km and almost all people who travelmore than 8 km have to surpass an altitude difference greater than 150 m, which greatly limits the use of conventional cycles and favours the use of electrical bicycles.

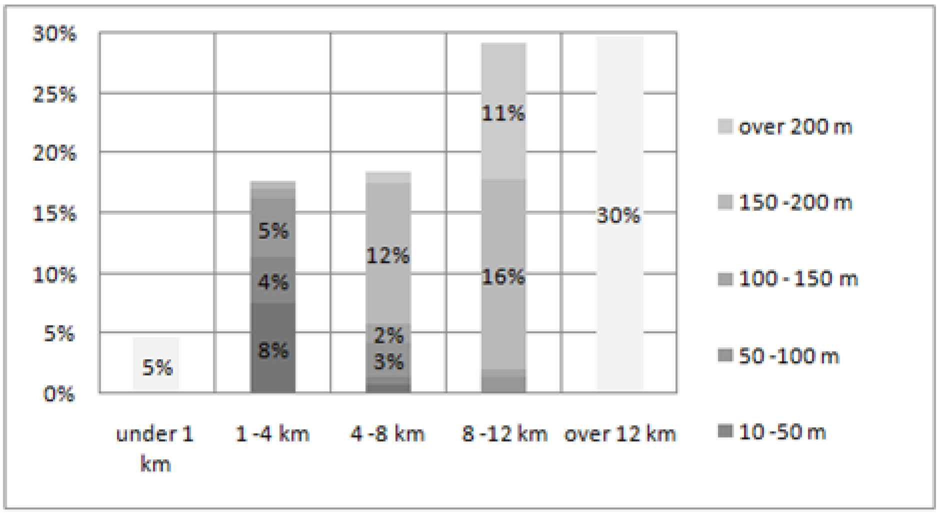

Figure 6: Calculated cumulative altitude differences between housing and work/study places along the cycle paths of the respondents of our survey.

Figure 7shows the distances from home to the chosen university campus calculated using Google Maps and divided into five categories: (*i*) less than 1 km, (*ii*) from 1 to 4 km, (*iii*) between 4 and 8 km,(*iv*) from8 to 12 km, and (*v*) more than 12 km.A total of 70% of the participantslive within 12 km of the campus they frequent most often, with 29%, 18%, 18%, and 5%of the participants living between 8 and 12 km, between 4 and 8 km, between 1 and 4 km, and ≤1 km away from the campus, respectively. In terms of the distances only,researchers may conclude that a significant number of people (~70%) could go to ULiège by bicycle or electric bicycle. The distance classes used above are based on the literature review [28,34,38,39], suggesting that the limit for a conventional bicycle home-to-work trip is ~8 km and the electric bicycle can beused for traveling a distance that is approximately 1.5 times longer than that covered with conventional bikes. Thus, we considered 12 km as the maximum distance for electric bicycles in this study. These distance classes also agree with the distances cycled based on our survey andthe Belgian national survey BELDAM (see Figures 4 and 5).

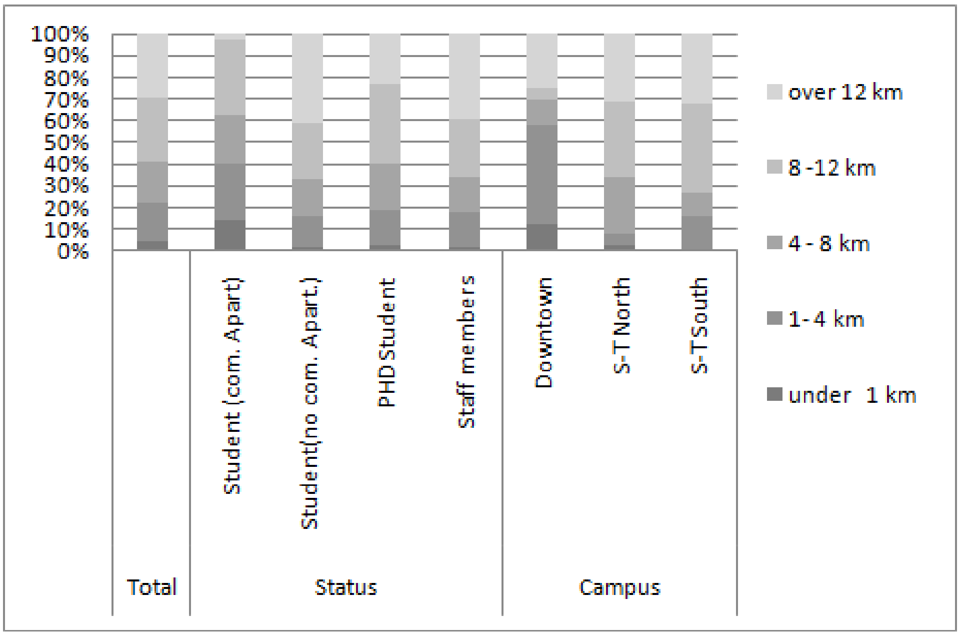

Figure 7: Distances travelled from home to the chosen university campus for the respondents of our survey and their distribution by status and campus.

Based on the comparison of the modal share of the bicycleaccording to the distances for home–university trips,the limit beyond which the conventional bicycle is much less used based on our survey seems to be ~4 km, while the bike is used as much between 4 and 8 km as between 8 and 12 km. The limit of 4 km agrees with the radius beyond which the topography becomes binding and the distance at which the modal share of the electric bike becomes much more important based on our survey. Below 1 km, the modal share of bicycles is less important than between 1 and 4 km but remains higher than that for distances greater than 4 km. Considering both the distance and terrain, the potential for bike and electric bike use is thus three times as high as that of conventional cycling.

Note that the majority of respondents going to the city centrecampus live within 4 km, whereas the majority of those going to the SartTilmancampuses live more than 8 km away from it, indicating a greater potential for walking and classic cycling downtown compared with a greater potential for electricbicycleuse for users of the SartTilman campus.

However, it is possible that people living at longer distances might have been underestimated because of sample bias, that is, people whofeel less involved in the survey and did notparticipate. Although the geographical context of the ULiège cannot be exactly applied to the context of the whole country of Belgium, Figure 8 shows that the home-to-work distances collected in this survey are consistent with those reported by Verhetsel et al. [49] for Belgium in 2007 who found that 21% of the workers live between 0 and 5 km away from their workplace, 39% live between 5 and 10km away, and 40% of them live over 10km away.Thus, one can assume that bias did not have a significant impact on this issue.

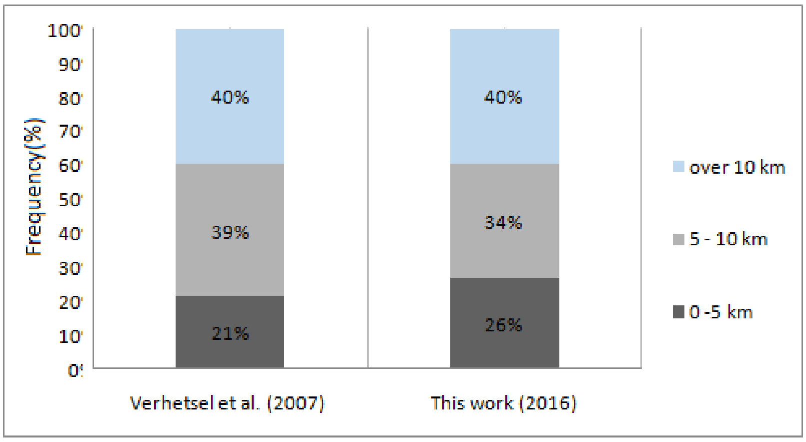

Figure 8: Comparison between home-to-work distances based on our survey and that reported byVerhetsel et al. [49].

4.2. Transportation mode analysis

To evaluate mobility habits, the respondents were asked two questions, that is, about the frequency of use of each mode of transport in everyday life and about the main mode of transport used for moving fromthe home locationto the university. The proportion of modes of transport used every day very strongly corresponds with the modal shares of the main modes of transport used for the home-to-university trips (Figure 9).It was noticed that the bike is almost used twice as much by men compared with women.

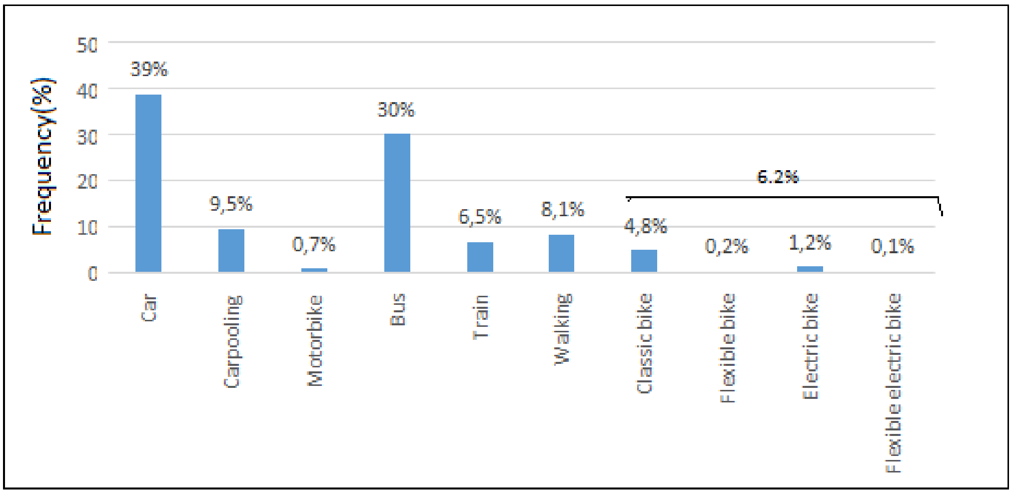

Figure 9: Percentage of respondents using a certain transport mode as their primary mode of transportation for home-to-university trips based on our survey.

Overall, bicycles had a modal share of 6.2% based on the sample, which is considerable largercompared with the 1.5% cyclists reportedin Wallonia according to the last nationalsurvey for home-to-work trips [41].Figure 10 compares the modal share observed in our survey with the modal shares of other surveys concerning ULiège [43, 44]: a recent survey (2014) of the mobility of the students of the University of Liège [43] and an older survey (2004) on the mobility of all uses of the SartTilmancampus [44]. Although these previous studies did notconsider all types of users andthe campus in the city centre and did not focuson (e)bikes, the data can becompared with the modal share observed in our survey.

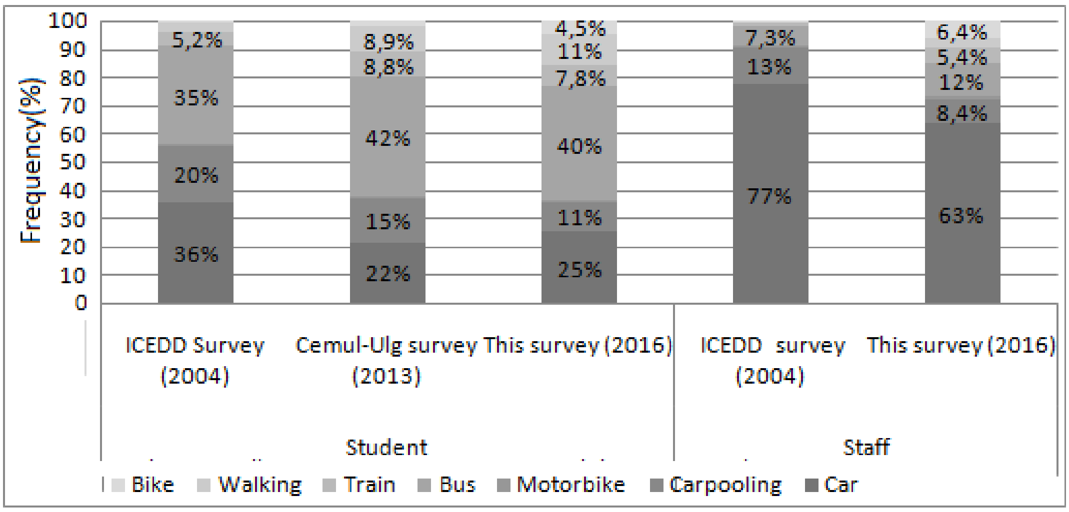

Figure 10: Comparison of the modal shareobserved in different surveys concerning ULiège[43, 44].

4.3Satisfaction with respect to the transport modes

Two questions were related to the satisfaction with respect to the main mode of transport used for the residence–ULiège trip. The first question simply asked the respondents whether or not they were satisfied with their primary mode of transportation (Figure 11).

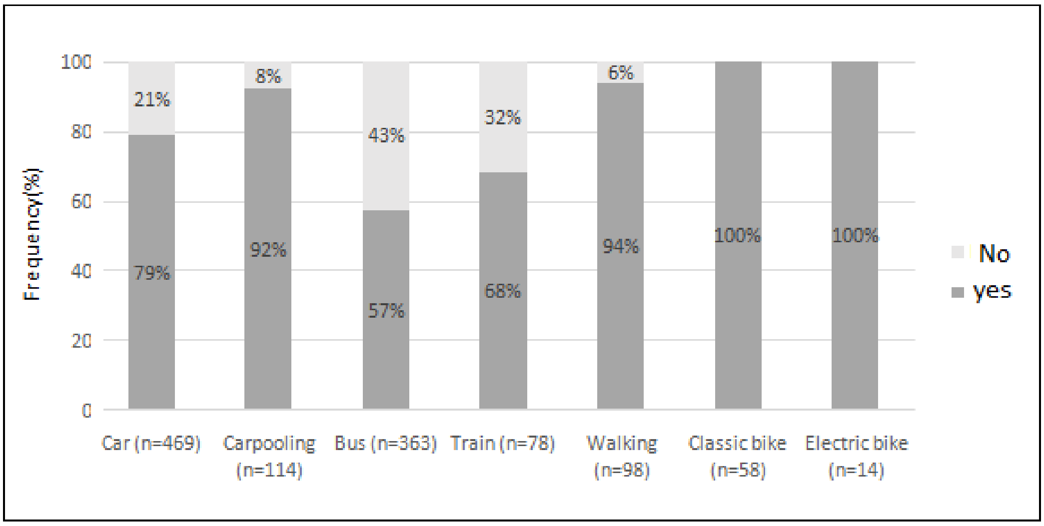

Figure 11: Answer of the respondents about their satisfaction with respect to their primary mode of transportation.

The second question asked the respondents how likely they were (on a scale of 0 to 10) torecommend this mode to a friend or colleague. The purpose of this question was to calculate the Net Promoter Score (NPS)for each mode of transport, which is an indicator of the user satisfaction and loyalty (see Figure 12).

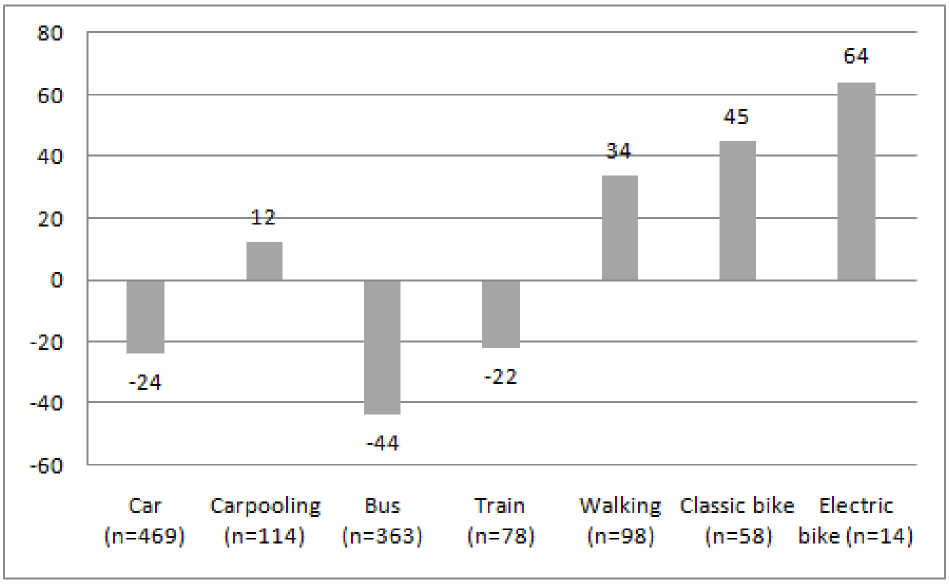

Figure 12: Net Promoter Score (NPS) calculated for each mode of transport based on our survey.

The NPS, developed in 2003 by Bain & Company's consultant Fred Reichheld[50], provides a standardised assessment of the extent to which a respondent recommends a certain company, product, or service to their loved ones. It is a simple, yet powerful, tool to measure the customer satisfaction and position yourself against the competition. Although it is mainly used to measure the satisfaction of a company or a product, it can also be used in a more specific context, for example, the transport market. The NPS methodology is based on a single question: 'How likely are you to recommend [company/product/service] to a friend or colleague?', with answers ranging from 0 to 10. The calculation is then based on the assumption that the customers can be divided into three categories: (*i*) Promoters who give a score of 9 or 10: loyal and enthusiastic customers who will continue to buy/use the product while advising others;(*ii*) Liabilities, giving a score of 7 or 8: satisfied but indifferent customers who will be sensitive to offers of the competition; and(*iii*) Detractors who give a score between 0 and 6: disgruntled customers, stuck in a bad relationship who can speak ill of the product and harm it.

The equation for calculating the NPS is very simple:

$$NPS = \frac{Number\ of\ promotors - Number\ of\ detractors}{Number\ of\ answering} \times 100 \qquad (1)$$

The NPS can range from -100 (all respondents are detractors) to 100 (all respondents are promoters). We evaluated if a NPS is good or bad by comparing it to other NPSs.The results show that this score is a good indicator of growth potential. The companies, products, or services that achieve the best NPS tend to outperform the rest of the market and achieve profitable long-term growth. Satisfaction with the use of motorcycles and folding bicycles is not included in these graphs because the sample was insufficient to obtain statistics. Authors have included the electric bike in the statistics.

Our hypothesis underlying these questions, that is, that active modes of transport are more satisfactory than the others, could be confirmed: walking and especially cycling are much more popular than motorised modes of transport including cars (see Figure 7). All bike users are satisfied and this is by far the mode of transport with the best NPS, the electric bicycleeven more than the conventional bicycle. On the other hand, aside from carpooling, motorised modes of transport (car, train, and bus) have a negative NPS, which implies that the users of cars, busses, or trainswould likely to change their modes of transport if another mode of transport met their needs.

These results showthat there indeed is a place for cycling, especially for the electric bicycle, in the transport market in Liègeand the university community. Within a distance from the ULiège that can be travelled by bike, the modal shift could be significant if the different limits of the use of the bike could be overcome. Although the context of our study is different, these affirmations confirm the results reported elsewhere [25-26].

4.4.Factors affecting conventionaland electricbicycleuse

The limitations cited by all respondents with respect to conventional and electric bicycles were analysed. A list of limitations was provided to all respondents. Tables 3 and 4 show the factors cited as limitationswith respect to the conventional and electric bicycles depending on the type of profile of the respondent. Conditional formatting was used to distinguish a significant limitation (dark orange) from a smaller limitation (light orange).

The lack of safe cycle lanes is a major obstacle with respect to the use of both conventional and electric bicycles as means of transport. The topographical relief is the most important limitation with respect to the use of the conventional bike, but its importance significantly decreases for the electric bicycle. It is cited by 2.6 times less peopleand transfersfrom the 1st to the 8th rank among 13 ranks in the order of the most important limitations for the electric bike. More generally, the importance given to many factors is lower if we consider the electric bicyclecompared with the conventional bicycle. Only few factors are more important for the electric bicycle than for the classic bicycle. The lack of parking is slightly more important for the electric bicycle.The price of the bicycle, which is of minimal importance for the conventional bicycle, obtains the 3rd rank for the electric bicycle. With respect to this, e-bike rental and sharing systems might be solutions that should bedeveloped. Another possibility that could help to overcome the price barrier of the electric bicycle would be to further make the users aware of the annual cost of using it compared with other transport modes.

The responses cited in the ‘Other’ category were very diverse. The most cited reasons were a short commute made just as fast on foot, the extra time needed to make the trip and take a shower, and the need for proper equipment (implying the impracticability of wearing a skirt or shoes with heels for women). Several respondents also cited the cold, lack of urban lighting, need or the obligation to use the car for professional reasons, not knowing how to ride a bicycle, or not owning one. Finally, a few respondents noted the lack of intermodality, lack of motivation, and health problems preventing them from pedalling, problems related to their schedules, fear of theft, or not liking to ride a bike.

Most of the limitations are perceived as more important by women than by men, which is consistent with the results obtained in China [51-52] and Europe [57-60]. Depending on the factors and type of bicycle, the difference varies from 1% to 10% more for women. This can be due to the complexity of the journey (e.g. children to transport) and insecurity. Note that these barriers seem to have been overcome in the Netherlands, that is, men and women have similar cycling rates in this country [61].It is more difficult to highlight an overall trend based on the status. The complexity of the journey is a limitation that is almost twice as important for staff members thanfor students or doctoral students, whereasthe price of the electric bicycle is considerably less important for staff members. Other significant differences concern the congestion, which is perceived as more important by students, and the lack of showers, more often cited by PhD students. For respondents who travel to the city centre most often, the topographical relief, distance, effort, presence of showers, and speed are less important factors than for respondents travellingto the SartTilman campus. Finally, if we compare the limitations according to the main mode of transport used by the respondents, mostfactors are much more frequently mentioned by the bus users than by car users. Only the distance, complexity of the journey, and speed are more important for car users.

		Relief	Bike path	Insecurity	Congestion	Distance	Effort	weather	Baths	Parking	Complexity	Speed	Traffic	Price	Other
Total		63	61	58	54	51	44	43	36	33	29	24	15	4	7
Sex	Male	61	60	53	50	49	41	40	44	35	24	26	15	3	8
	Female	64	61	61	57	53	45	45	30	32	32	24	14	4	6

Status	Student	67	64	58	62	54	45	49	36	38	26	28	13	5	5
	PHD student	62	68	64	50	40	42	43	44	34	19	19	16	2	11
	staff	57	54	56	42	50	42	33	33	25	37	20	16	1	8
Campus	Downtown	51	59	58	54	46	36	46	27	40	29	16	13	6	8
	ST North	67	62	57	54	55	46	41	40	29	28	28	14	3	6
	ST South	67	61	59	56	49	45	46	35	36	30	26	17	3	9
Mode of transport	Car	60	55	54	51	58	40	41	36	29	37	27	14	0	7
	Bus	73	69	65	58	46	53	46	39	33	23	26	16	7	4

Table3: Limitations with respect to the use of conventional cycling as a mode of transport according to the type of respondent profile (in%).

		Bike path	Insecurity	Price	Congestion	Weather	Distance	Parking	Relief	Complexity	Bath	Speed	Effort	Traffic	Other
Total		47	47	42	41	35	34	33	24	23	22	12	11	11	9
Sex	Male	47	44	44	35	32	30	33	21	18	25	12	9	11	11
	Female	48	50	41	45	37	37	33	25	26	20	12	12	11	8
Status	Student	47	46	48	46	39	35	36	26	18	21	15	12	10	8
	PHD student	50	52	50	39	33	27	35	19	16	29	7	7	11	12
	staff	47	49	30	33	29	36	28	22	33	22	9	11	14	10
Campus	Downtown	41	44	46	38	32	28	32	14	19	16	6	7	8	10
	ST North	50	49	40	41	35	38	30	27	23	25	15	13	12	8
	ST South	49	48	42	43	38	33	40	25	24	22	11	11	13	10
Mode of transport	Car	46	46	32	40	35	41	30	25	32	23	13	10	12	9
	Bus	52	52	52	42	38	27	35	26	15	23	12	13	11	6

Tableau 4: Limitations with respect to the use of electric cycling as a mode of transport according to the type of respondent profile (in%).

To promote the use of bicycles (bikes and electric bikes), the priority must absolutely be the development of a safebicycle infrastructure, where such infrastructure is not yet present on the whole campus and/or various access roads. Finally, other factorsshould not be forgotten and should be implemented for support and reinforcement in addition to thecreation of secure routes from the city centre to ULiège.Compared with other motorised modes of transportation, electric bicycles reduce the rate of carbon emissions, which significantly impact human health, the most [56, 61].

4.5. Conditions for a modal report toward a bike type

Under the current conditions (no secure bike parking in the streets, no rental system), having a place to park your bike at the home location is a prerequisite for getting around by bike. Interestingly,most ofthe respondentsalready had a secure bike slot at their home; only 10% of the respondents were dissatisfied.

To identify the most effective cycling promotion strategies, the respondents were asked if they would consider cycling,either with a conventional or electric bicycle, more often (or occasionally if they did not use it before) under the following conditions: (*i*)if there were bike lanes on their route; (*ii*) if they received compensation of 0.22 €/km (for a round trip downtown–SartTilman campus five times per week, equivalent to an allowance of 80 €/month); (*iii*) if there were more bike parking facilities and showers at the university; (*iv*) if they could take a bike on public transport modes, (*v*) if there were evenmore traffic jams; (*vi*) if they received financial help with respect to the purchase of a bike; (*vii*) if the costs associated with the car were to increase significantly (e.g. paid parking everywhere, fuel prices, urban tolls, taxes); (*viii*) if several people they know would start using the bike as a mode of transportation and recommend it to them; and (*ix*) if there were bike sharing rental stations near their home and at the university. The last question was only addressed to people who did not use the bicycle as their primary means of transportation, which corresponds to 1131 respondentsor 94% of the sample. Table 5 shows the proportion of the respondents (in total and by type of profile) who agreed that they would consider cycling or electric cycling (more often) based on the proposed conditions. Similar to the importance of the influencing factors, conditional formatting was used to distinguish the effectiveness of the proposed measures.

		Bike lanes	Allowance: 0.22 €/km	Bike parks & showers	Public transport modes	More traffic jams	Help: bike purchase	Higher cost for car use	Recommendations	Rental stations
Total		71	57	53	43	42	42	36	34	31
Sex	Male	71	63	58	42	48	40	41	33	30
	Female	71	53	50	43	38	43	32	35	33
Status	Student	74	66	56	51	44	45	37	45	35
	PHD student	82	66	70	43	51	52	39	35	37
	staff	62	38	43	29	36	33	32	16	23
Campus	Downtown	72	57	51	45	40	46	31	35	39
	ST North	67	55	52	43	41	38	34	33	28
	ST South	78	62	58	41	46	46	43	37	31
Mode of transport	Car	62	46	46	28	40	33	39	23	23
	Bus	82	70	60	58	47	51	33	46	36

Table 5: Proportion of the respondents who would consider cycling more often based on the proposed conditions and type of respondent profile (in%).

Note that the questions did not ask the respondents if they would use the bicycleas their primary mode but only if they would use it more often. The percentages therefore do not account for the complete modal shift, but are indications of measures that can gradually contribute to the reduction of the use of less environmental transport modes such as the car or bus.

The conditions that would encouragethe most people to travel by bike more often are in order of descending importance:the development of bike paths, allowance, and installation of bike parking and showers at the university campuses. Note that none of the proposed conditions seem to be ineffective. However, the only strategy that would motivate an increase in the use of cycles to go to the university by more than 40% of the staff members is the creation of bike paths, which could increase the bike use by 74% of students, 82% of PhD students, and 62% of staff members. It is therefore the main strategy that should be favoured. This strategy could also increase the use of bicycles or e-bikes to travelto the university by 62% of car users and 82% of bus users.

5. Conclusion

Pollution, oil dependency, traffic jams, and the lack of space for car parksare among the reasons pushing the current society to develop alternative mobility solutions to the individual car. This research aimed at analysing the possibility of a modal shift toward conventional and electric bicycles. The three main campuses of the University of Liège in Belgium were used in a case study. The first part of the study explains the research methodology and the results of a literature review on the benefits, influencing factors, and modal shift potential of electricbicycles in European cities.The case study is discussed in the second part of the paper. A survey was conducted among the university population of Liège and 1496 responses were recorded. All results were analysed according to the type of respondent profile (gender, status, campus area attended, main mode of transportation) and interesting differences were highlighted.

In total, 70% of respondents live within a distance of the ULiège that can reasonably be travelled using a conventional or electric bicycle. The results of the survey show thatboth conventional and electric bicycles are transport modes that are more appreciated by their users than cars, buses, and trains.The lack of a safe bicycle infrastructureis the major obstacle to the use of both conventional and electric bicycles. The topographical relief is the most important limitation with respect to the use of the conventional bikes, which can be overcome by the electric bike. The importance given to many limitations with respect to the use of bicycles is lower if we consider the electric bicycleinstead of the conventional bicycle.

Finally, based on the results and analyses, several strategies could be utilised to promote the use of conventional and electric bicycles.When searching for the conditions for a modal report toward classic and electric bicycles, the electric bicycle is chosen more often as an alternative mode of transport than the bike by women and staff members. The best strategy that would motivate an increase in the use of bicycles to travelto the university is the creation of secure bike paths within a radius of 12 km around the university campuses,which could increase the bike use by 74% of students, 82% of PhD students, and 62% staff members as well as 62% and 82% of the car and bus users, respectively. However, we must remain realistic and remember that there are big differences between the results of stated preference studies and the levels of cycling that will be achieved.

The methodology developed in this article can be reproduced in other urban regions in Belgium but also in Europe or beyond.The reproduction of the methodology in other European cities should lead to the same observations. However, it would also be interesting to compare our results with those that would be collected in other Belgian surveys on other emerging mobility types (e.g. autonomous electric cars, car sharing networks, scooters, roller skates), especially to evaluate their Net Promoter Score (NPS). In this study, only 14 respondents used electric bikes as their main commuting mode; in the future, our study will consider a larger territory to obtain resultsbased on a greater number of electric bike commuters.

To extend this study, the authors suggest to study cycling as a mode of transport in a multimodal chain as well as ways to promote the intermodality for conventional and electric bicycles. Finally, calculations of the future energy consumption and CO_2 emissions reduction based on modal share projections with respect to an increase in (e)bike uses could help to implement European and United Nationssustainable development goals in the future.

Acknowledgment

The authors acknowledge the AXA companyfor their financial support and the LEMA laboratory team of the University of Liège, where the research was carried out.

References

[1] Sustainable Cities International. (2012). Indicators for Sustainability : How cities are monitoring and evaluating their success. (Consulted April 12 th, 2016). http://sustainablecities.n et/wp-content/uploads/2015/10/indicators-for-sustainability-intl-case-studies-

[2] IEA (International Energy Agency). (2009). Transport, Energy and CO2: Moving Toward Sustainability. Paris, France.

[3] Kahn Ribeiro, S., & Kobayashi, S. (2007).Transport and its infrastructure. In B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, & L.A. Meyer (Eds.), *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK and New York, NY : Cambridge University Press.

[4] Figueroa, M., Lah, O., Fulton, L. M., McKinnon, A., & Tiwari, G. (2014). Energy for Transport.*Annual Review of Environment and Resources*, *39*(1), 295-325.

[5] IEA (International Energy Agency). (2010). World Energy Outlook 2010.Paris, France.

[6] Cooper, A., Page, A., Foster, L., &Qahwaji, D. (2003). Commuting to school: are children who walk more physically active*? American Journal of Preventive Medicine, 25*(4), 273–276.

[7] Frank, L.D., Andresen, M.A., &Schmid, T.L. (2004). Obesity relationships with community design, physical activity, and time spent in cars. *American Journal of Preventive Medicine, 27*(2), 87–96.

[8] Vandenbulcke, G., Dujardin, C., Thomas, I., Geus, B. de, Degraeuwe, B., Meeusen, R., & Panis, L. I. (2011). Cycle commuting in Belgium: Spatial determinants and 're-cycling' strategies. *Transportation Research Part A: Policy and Practice*, *45*(2), 118-137.

[9] Tolley, R. (1996). Green campuses: cutting the environmental cost of commuting. *Journal of Transport Geography*, *4*(3), 213–217.

[10] Marique, A.-F. & Reiter, S. (2012). A method for evaluating transport energy consumption in suburban areas. Environmental Impact Assessment Review, 33, 1-6.

[11] Cole-Hunter, T., Donaire-Gonzalez, D., Curto, A., Ambros, A., Valentin, A., Garcia-Aymerich, J., Martínez, D., Braun, L.M., Mendez, M., Jerrett, M., Rodriguez, D., de Nazelle, A., &Nieuwenhuijsen, M. (2015). Objective correlates and determinants of bicycle commuting propensity in an urban environment. *Transportation Research Part D: Transport and Environment*, *40*, 132-143. http://doi.org/10.1016/j.trd.2015.07.004

[12]Héran, F. (2012). *Vélo et politique globale de déplacements durables*. Consulté à le 11 avril 2016 l'adresse http://www .predit.prd.fr/ predit4/documentFo.fo?cmd=vi sualize&inCd.

[13] Bachand-Marleau, J., Lee, B.H.Y., & El-Geneidy, A.M. (2012). Better understanding of factors influencing likelihood of using shared bicycle systems and frequency of use. *Transportation Research Record: Journal of the Transportation Research Board,* 2314.

[14] Rotaris, L., &Danielis, R. (2015). Commuting to college: The effectiveness and social efficiency of transportation demand management policies.*Transport Policy*, *44*, 158-168.

[15] Santos, G., Maoh, H., Potoglou, D., &vonBrunn, T. (2013). Factors influencing modal split of commuting journeys in medium-size European cities. *Journal of Transport Geography*, *30*, 127-137. http://doi.org/10.1016/j.jtrangeo.2013.04.005

[16] Rietveld, P., & Daniel, V. (2004). Determinants of bicycle use: do municipal policies matter? *Transportation Research Part A: Policy and Practice, 38*, 531–550.

[17] Wardman, M., Tight, M., & Page, M. (2007). Factors influencing the propensity to cycle to work.*Transportation Research Part A: Policy and Practice, 41*, 339–350.

[18] Van Malderen, L., Jourquin, B., Thomas, I., Vanoutrive, T., Verhetsel, A., &Witlox, F. (2009). Mobility policies of the companies located in Belgium: are there success stories? In: *Proceedings of the BIVEC-GIBET Transport Research Day, third ed., Belgium, May 27, 2009*, Brussels, VrijeUniversiteit Brussel (VUB).

[19] Cass, N., &Faulconbridge, J. (2016). Commuting practices: New insights into modal shift from theories of social practice.*Transport Policy*, *45*, 1-14.

[20] Rodriguez, D.A., Joo, J. (2004). The relationship between non-motorized mode choice and the local physical environment.*Transportation Research Part D: Transport and Environment*, *9*, 151–173. http://dx.doi.org/10.1016/j.trd.2003.11.001

[21]Robinson, D. L. (2006). No clear evidence from countries that have enforced the wearing of helmets. *British Medical Journal*, *332*(7543), 722-725. Consulté à l'adressehttps://www.ncbi.nlm.nih.gov/pmc/articles/PMC1410838/

[22]Pucher, J., & Buehler, R. (2008).Making cycling irresistible: lessons from the Netherlands, Denmark and Germany. *Transport Reviews, 28*(4), 495–528.

[23] Heinen, E., van Wee, B., & Maat, K. (2010). Commuting by bicycle: an overview of the literature.*Transport Reviews, 30*(1), 59–96.

[24] Winters, M., Davidson, G., Kao, D., &Teschke, K. (2010). Motivators and deterrents of bicycling: comparing influences on decisions to ride. *Transportation*, *38*(1), 153-168.http://doi.org/10.1007/s11116-010-9284-y

[25] Broach, J., Dill, J., &Gliebe, J. (2012). Where do cyclists ride? A route choice model developed with revealed preference GPS data. *Transportation Research Part A: Policy and Practice, 46*, 1730–1740.

[26] Buehler, R. (2012). Determinants of bicycle commuting in the Washington, DC region: The role of bicycle parking, cyclist showers, and free car parking at work. *Transportation Research Part D: Transport and Environment, 17*, 525–531.

[27] Yang, L., Hipp, J. A., Adlakha, D., Marx, C. M., Tabak, R. G., &Brownson, R. C. (2015). Choice of commuting mode among employees: Do home neighborhood environment, worksite neighborhood environment, and worksite policy and supports matter? *Journal of Transport & Health*, *2*(2), 212-218.http://doi.org/10.1016/j.jth.2015.02.003

[28] Dickinson, J.E., Kingham, S., Copsey, S., & Pearlman Hougie, D.J. (2003). Employer travel plans, cycling and gender: will travel plan measures improve the outlook for cycling to work in the UK? *Transportation Research Part D: Transport and Environment, 8*, 53–67

[29]Langford, B. C., Chen, J., & Cherry, C. R. (2015). Risky riding: Naturalistic methods comparing safety behavior from conventional bicycle riders and electric bike riders. *Accident Analysis&Prevention*, *82*, 220-226. http://doi.org/10.1016/j.aap.2015.05.016

[30] Bike Europe. (2013). *Europe's E-Bike Imports IndicateMarket Size*. Consulté le 14 avril 2016 à l'adresse http://www.bike-eu.com/sales-trends/nieuws/2013/8/europes-e-bike

[31] Weinert, J., & Van Gelder, E. (2009). Light Traction: Batteries. In *Encyclopedia of Electrochemical Power Sources,* 292-301. Amsterdam: Elsevier. Consultéàl'adressehttp://www.sciencedirect.com/science/article/pii/B9780444527455003749

[32] Cherry, C. R., Weinert, J. X., &Xinmiao, Y. (2009). Comparative environmental impacts of electric bikes in China. *Transportation Research Part D: Transport and Environment, 14*(5), 281-290. http://doi.org/10.1016/j.trd.2008.11.003

[33] Ji, S., Cherry, C.R., Bechle, M.J., Wu, Y., Marshall, J.D. (2012). Electric vehicles in China: emissions and health impacts. *Environmental Science & Technology, 46*, 2018–2024.

[34] Weiss, M., Dekker, P., Moro, A., Scholz, H., & Patel, M. K. (2015). On the electrification of road transportation – A review of the environmental, economic, and social performance of electric two-wheelers.*Transportation Research Part D: Transport and Environment*, *41*, 348-366. http://doi.org/10.1016/j.trd.2015.09.007

[35] Cherry, C. R., Yang, H., Jones, L. R., & He, M. (2016). Dynamics of electric bike ownership and use in Kunming, China.*Transport Policy*, *45*, 127-135.

[36] Langford B.C., Cherry C.R., Bassett D.R., Fitzhugh E.C. (2017). Comparing physical activity of pedal-assist electric bikes with walking and conventional bicycles. Journal of Transport and Health 6 : 463 – 473.

[37]Jones, T., Harms, L., &Heinen, E., (2016). Motives, perceptions and experiences of electric bicycle owners and implications for health, wellbeing and mobility. *Journal of Transport Geography, 53,* 41-49.

[38]Wolf, A., &Seebauer, S. (2014). Technology adoption of electric bicycles: A survey among early adopters. *Transportation Research Part A: Policy and Practice*, *69*, 196-211.

[39] Cairns, S., Behrendt, F., Rafflo, D., Beaumont, C., & Kiefer, C. (2017). Electrically-assisted bikes: Potential impacts on travel behaviour. *Transportation Research Part A: Policy and Practice, 103,* 327-342.

[40] European Cyclists' Federation (ECF), (2017). EU cycling strategy.Recommendations for delivering green growth and en effective mobility system in 2030**,** 161p. (Consulted in June 2018) https://ecf.com/sites/ecf.com/files/EUCS_full_doc_small_file.pdf

[41] Pauwels, C., & Andries, P. (2016). *Diagnostic des Déplacements Domicile - Lieu de Travail 2014*. Bruxelles : SPF Mobilité et Transports.

[42] European Cyclists' Federation (ECF). (2011). Cycle more often 2 cool down the planet: Quantifying CO2 savings of cycling. (Consulted in June 2018).https://ecf.com/sites/ecf.com/files/ECF_CO2_WEB.pdf

[43] Bianchet, B. (2014). Enquête Cemul-ULg : Mobilité des étudiants de l'Université de Liège, Principaux résultats.(Translation :*Cemul-ULg survey: Mobility of students of the University of Liège, Main results*).

[44] Institut de Conseil et d'Études en Développement Durable (ICEDD). (2004). Plan de transport d'entreprise du Sart Tilman : Analyse des résultats des enquêtes mobilité menées auprès du personnel, des étudiants, des patients et des visiteurs.(Translation :*Intitue of Consulting and Studies in Sustainable Development (ICEDD) (2004). SartTilman Corporate*

Transportation Plan: Analysis of mobility survey results from staff, students, patients and visitors.)

[45] Cornelis, E., Hubert, M., Huynen, P., Lebrun, K., Patriarche, G., De Witte, A., Walle, F. (2012). *La Mobilité en Belgique en 2010 : Résultats de l'Enquête BELDAM*. (Consulted in June 2018): https://www.mobilit.fgov.be/Applications/Internet/beldamwww.nsf/Documents?OpenForm

[46]Van Zeebroeck, B., Charles, J., &Holef, E. (2014).*Évaluation économique de la pratique du vélo en Wallonie*. Namur : SPW Direction Générale Opérationnelle de da Mobilité et des Voies Hydrauliques.

[47] Reiter, S., &Marique, A.-F. (2012). Toward low energy cities : A case study of the urban area of Liège. Journal of Industrial Ecology, 16(6), 829-838.

[48] Marique, A.-F., Dujardin, S., Teller, J., & Reiter, S. (2013). School commuting: the relationship between energy consumption and urban form. Journal of Transport Geography, 26, 1-11

[49] Verhetsel, A., Thomas, I., Van Hecke, E., &Beelen, M. (2007). Monografie van het Woonwerkverkeer in Belgïe.Belgian Science Policy and FPS Mobility and Transports.

[50] Bain & Company. (s.d.).Measuring your Net Promoter Score.Consulté le 01 juin 2016 à l'adresse http://www.netpromotersystem.com/about/measuring-your-net-promoter-score.aspx

[51] Cherry, C. R. &Cervero, R. (2007). Use characteristics and mode choice behavior of electric bike users in China. *Transport Policy, 14*, 247–257.

[52] Cherry, C. R. (2007). Electric Bike Use in China and Their Impacts on the Environment, Safety, Mobility and Accessibility. UC Berkeley Center for Future Urban transport, Working Paper, UCB-ITS-VWP-207-3. Consulté le 22 mai 2016 à l'adressehttp://escholarship

[53] Topographic-map.com. (s.d.). Liège. Consulté le 01 juin 2016 à l'adresse http://fr-be.topographic-map.com/places/Li%20%C3%20%A8ge-6937/

[54] University of Liege (ULg).2016(*AccesJuillet* 2017) .https://www. ulg.ac.be/ cms/c_ 5876778/fr/ acces-et-plans.

[55]Université de Liège (ULg). (2014). *Incitants financiers*.(Access juillet 2018) https://www.ulg.ac.be/cms/c_3347421/fr/incitants-financiers

[56] Lovelace, R., Goodman, A., Aldred, R., Berkoff, N., Abbas, A.,&Woodcock, J. (2017). The Propensity to Cycle Tool: An open source online system forsustainable transport planning. *Journal of Transport and Land Use*10:505-528.

[57] Aldred, R., Elliott, B., Woodcock, J., &Goodman, A.(2017). Cycling provision separated from motor traffic: a systematic review exploring whether stated preferences vary by gender and age.*Transp Rev*. 37(1): 29–55.

[58]Chataway, E. S., Kaplan, S., Nielsen, T. A. S., &Prato, C. G. (2014). Safety perceptions and reported behavior related to cycling in mixed traffic: A comparison between Brisbane and Copenhagen. *Transportation Research Part F: Traffic Psychology and Behaviour*. 23:32–43. doi: 10.1016/j.trf.2013.12.021.

[59]Heinen, E., van Wee, B., &Maat, K. (2010). Commuting by bicycle: an overview of the literature.*Transport Reviews*.30(1):59–96. doi: 10.1080/01441640903187001.

[60]Krizek, K. J., Johnson, P. J., &Tilahun, N. (2005). Gender differences in bicycling behavior and facility preferences. Research on Women's Issues in Transportation, Volume 2: Technical papers Report of a Conference. *Transportation Research Board Conference Proceedings* :31–40.

[61] Goodman, A., Rojas, I.F., Woodcock, J., Aldred, R., Berkoff, N., Morgan, M. Abbas, A., & Lovelace, R.(2019). Scenarios of cycling to school in England, and associated health and carbon impacts: Application of the 'Propensity to Cycle Tool'.*Journal of Transport & Health*12 : 263-278.