A comparative cost-benefit analysis of cycling within the Benelux and North Rhine-Westphalia

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Executive summary

Cycling is an active form of passenger transport that plays an unique role in our transport system. Riding a bicycle provides **affordable transport, improved health and enjoyment**. Regular cycling benefits users directly, but there are also **significant gains for society** as a whole. This means that even people who do not use a bike, benefit from others who do.

In this project, we investigate the **social costs and benefits of cycling in the Benelux and North Rhine-Westphalia (NRW)**. We investigate the potential for cycling in this region and analyse the benefits than can be achieved by a modal shift from passenger cars or public transportation to bicycles. Next, we develop a case study on a potential **cross-border cycling highway** between Arlon and Luxembourg. Finally, our study leads to specific **policy recommendations** to further stimulate cycling in the region.

Policy context: regions and countries have their cycle plans

Because of the large social benefits of cycling, there is growing attention for cycling among public authorities and policy makers. Recently, several countries and regions developed dedicated action plans to stimulate cycling. We name a few examples:

- In Germany, the **National Cycling Plan 3.0 (NCP3.0)** has the ambition to transform to country into a cycling nation. By 2030, the NCP3.0 foresees a significant increase in cycling mileages.
- The Belgian government has developed the **Be Cyclist Action Plan** that contains several action points from 2021 to 2024 to stimulate a regular use of the bicycle.
- In Luxembourg, a key role to cyclists is given in the **National Mobility Plan 2035 (PNM 2035)**. The PNM 2035 has the objective to drastically increase the modal share of cycling through integrating high-quality cycling infrastructure in all road projects.
- **National Cycling Vision of the Future** is a product by the Tour de Force. It presents the measures and investments needed to further stimulate cycling in the Netherlands.

Several initiatives exist to stimulate cycling. All countries provide **financial incentives** to cyclists, although in different forms. While Luxembourg offers a generous subsidy for the purchase of a new bicycle, a bicycle commuting allowance is granted in Belgium, the Netherlands and NRW. Apart from these national incentives, regional and local financial support for cycling exists.

Apart from these financial incentives, cycling is stimulated through the investment in new or existing **cycling infrastructure** and the creation of dedicated **cycling networks** (e.g. Holland Cycling Routes, Fietsnet, RAD Verkehrsnetz).[1,2,3]

Cycle highways encourage and accommodate cycling over longer distances. A cycle highway is a high-quality cycling route consisting of cycle lanes or tracks that separate cyclists from other road users.[4] They serve as transport corridors and typically connect two main cities. They accommodate commuters, students and tourists. Cycle highways lead to lower travel times for cyclists and

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[1] https://www.hollandcyclingroutes.com/

[2] https://www.fietsnet.be/routeplanner/default.aspx

[3] https://www.radverkehrsnetz.nrw.de/

[4] https://transport.ec.europa.eu/transport-themes/clean-transport-urban-transport/cycling/guidance-cycling-projects-eu/cycling-measures/13-cycle-highways_en

improve traffic safety. However, they are expensive to build, so should be used intensively to justify the costs.

Cost-benefit analysis of cycling in the Benelux and NRW: EACH KM CYCLED PROVIDES A BENEFIT TO SOCIETY

In the cost-benefit analysis we identify and monetize all costs and benefits that sprout from cycling and compare them with the costs and benefits of other modes for passenger transport. We include **private costs and benefits** and **external effects**. Together, they determine **the net social costs (if negative) or benefits (if positive)** of cycling. We do this for each of the Benelux countries and for NRW.

In the cost-benefit analysis, we consider the following aspects:

- **Total costs of ownership**: in general, a bicycle is cheaper to own and use than a passenger car.
- **Time costs**: because bicycles are slower than other modes of transport, they incur higher time costs to the user. However, this is not always the case in an urban environment, where (e)-bikes move faster than cars. In addition, bicycle riders loose less time searching for a parking spot.
- **Congestion costs**: driving a passenger car leads to significant congestion costs, which can be avoided by riding a bicycle.
- **Health benefits**: cycling contributes to physical and mental health, leads to lower mortality rates and prevents serious diseases. Regular cycling leads to savings in social security costs and a higher labour productivity.
- **Emissions**: while a passenger car emits CO_2 and other air pollutants like fine particles, bicycles generate no direct emissions. Therefore, riding a bicycle instead of a car reduces the CO_2 footprint and contributes to cleaner air.
- **Accidents**: currently accident risk and accident costs of cycling are higher than those of other passenger transport modes. To improve safety for all road users, investments in cycling infrastructure that separates cyclists from other road users are needed.
- **Noise**: bikes are silent. Cycling does not create noise pollution, in contrast to passenger cars, buses and trains.
- **Occupation of public space and quality of the living environment**: bicycles require less space than cars, both for parking and when in motion. In addition, cycling areas improve the liveability of a neighbourhood and prevent urban sprawl.
- **Infrastructure**: cycling infrastructure costs significantly less than road infrastructure for cars or public transportation.

We monetize all the above mentioned effects of cycling for the Benelux-NRW region. Country-specific costs and benefits are provided in the report. The social costs and benefits of the different passenger transport modes are represented by the black line in the figure below. They are comprised of private costs and benefits and external effects.

Every kilometre covered by a bicycle generates a net gain to society. The net benefits from riding a push bike are equal to 98 eurocent per kilometre. Each kilometre covered by an e-bike yields 22 eurocents in social gains. In contrast, a trip by car (as driver or as passenger) leads to a social cost of € 1.02 per km. **Differently put, if 100 000 people commute to work by push bike over a 5-km one-way distance, they generate a total benefit of 196 million euro per year. If they commute by car, they create a cost of 203 million euro per year. Of this total cost, 89 million euro is carried by the car user, but 114 million euro is for the rest of society to bear.**

The costs of riding a speed pedelec are all borne by the user (private costs). The external effects of speed pedelecs are positive, meaning that the rest of society benefits from speed pedelec activity.

The reason why cycling is so beneficial to society is mainly because of the positive health effects from regular cycling. Cycling prevents premature death and many severe and chronical diseases. It contributes to a healthier and happier life. These positive health effects are translated into lower social security expenses, a higher level of labour productivity and reduced absenteeism from work. Because the value of labour productivity in the Benelux-NRW is relatively high, the **productivity gains from cycling lead to high economic gains**. The positive health effects from cycling are so large that they compensate all related costs, including the costs of infrastructure. Therefore, **an investment in cycling infrastructure is an investment in public health**.

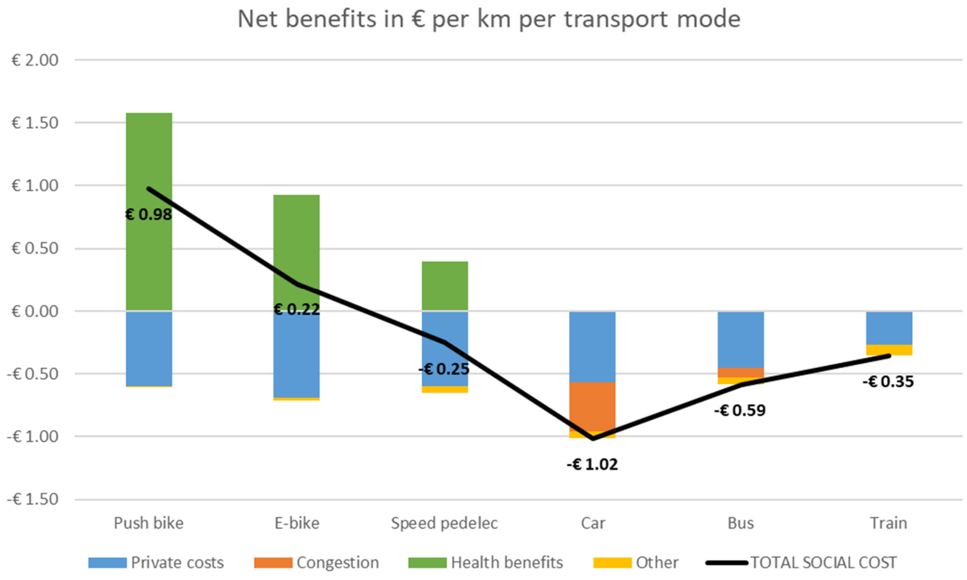

Figure 0-1 Social costs and benefits of passenger transport in the Benelux and NRW

The social costs and benefits represented in the figure above are expressed in per kilometre terms. When we take into account the average mileage of each transport mode, we can calculate the total benefit or cost an average person creates when choosing a mobility mode. **Every cyclist generates a net benefit ranging from € 260 to € 694 per year**. **Each car that drives 15 000 km per year, causes an annual social cost of € 15 227**.

Our results imply that **the economic value of a modal shift from passenger cars to bike rides is very large**. In per-kilometre terms, a modal shift to cycling is the highest for push bikes. A modal shift from passenger cars to biking leads to the largest benefits to society. The benefits are the result of the positive health effects that cycling generates, combined with the savings in congestion costs from lower car use. Other effects such as avoided CO2-emissions, clear air and avoided noise pollution also contribute to the social gain of a modal shift to cycling.

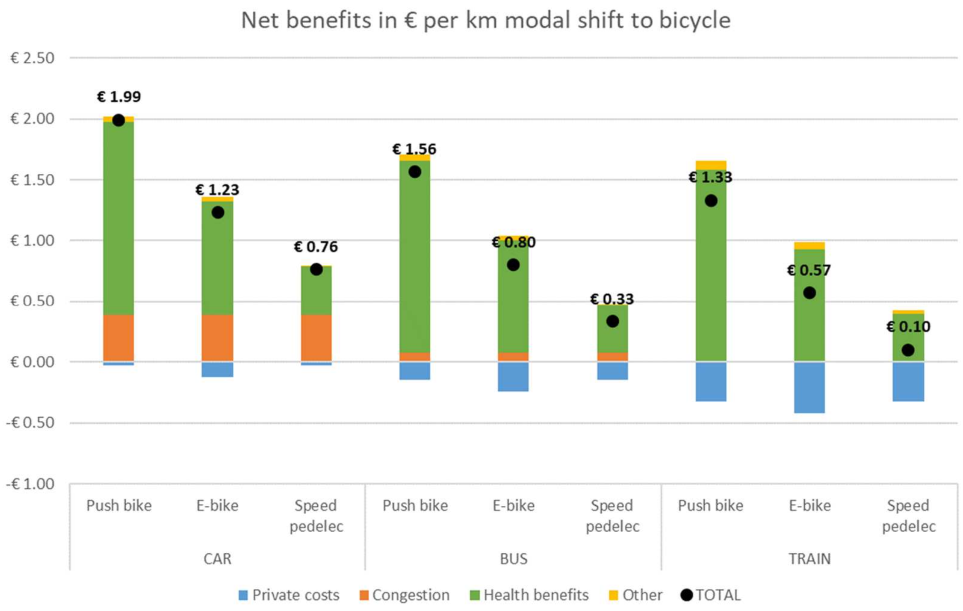

Figure 0-2 Impact of a modal shift to cycling in the Benelux-NRW

The lower per-kilometre gains from a modal shift to pedal-assisted bicycles are largely compensated by the higher distances covered on these bikes. Research shows that the average distance travelled on an e-bike is 1.7 times longer than by a push bike. Speed pedelecs cover trips that are 4 times longer on average that push bike rides. Each five-kilometre car trip that is replaced by a ride on a push bike leads to a net social gain of 10 euro. A 8-km car trip that is exchanged for an e-bike ride yields 9.8 euro to society. Riding a speed pedelec instead of a passenger car over a distance of 20 kilometres yields even 15.5 euro in social benefits.

Because 44% of all passenger car trips have a shorter distance than 5 km and 79% of all car trips are shorter than 20 km, the potential social benefits of a modal shift to cycling are enormous.[5] If **1% of all passenger-kilometres by car in the Beneluw-NRW are replaced by bicycle kilometres** (40% push bikes, 40% e-bikes, 20% speed pedelecs), a **net social gain of € 13.6 billion** can be realised.

A modal shift from public transport to cycling also results in social gains, although lower than when a car trip is replaced. In addition, train rides typically cover large distances that are not easily exchanged for bike rides. Therefore, the focus should be on accommodating **multimodal bicycle-inclusive mobility** rather than a modal shift from public transportation to cycling. Multimodal trips combine the advantages of cycling with those other transport modes (Tetteroo, 2015) (BiTiBi, 2016).

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[5] Monitor (2019).

Case study: Arlon – Luxembourg cycling corridor: at least 80% more benefits than costs with a significant upgrade of existing infrastructure

Arlon-Luxembourg: highest cross-border potential and no existing plans

We investigate the potential of several cross-border cycle highways. Connections with the highest potential are:

- Arlon-Luxembourg
- Gent-Terneuzen
- Venlo-Mönchengladbach/Krefeld
- Maastricht-Genk/Hasselt
- Heerlen/Landgraaf Aachen

Among those, the Arlon-Luxembourg connection provides the highest potential. It is also the only corridor for which no cycle highway is planned already.

Two cycle highway alternatives: upgrading existing infrastructure or building a new cycle highway

Among four alternative possibilities for the cycle highway, we short-listed two alternatives: a scenario that involves upgrading existing infrastructure (alternative 2), and a scenario that consists of building complete new infrastructure (alternative 4).

At least 80% more benefits than costs in the improved infrastructure alternative

Based on literature, we posed several assumptions in order to estimate the potential gains and costs and benefits of the cycle highway. Table 0.1 shows the main results for different scenarios.

with 7% modal share (transport plan Luxembourg)						
	Alt 2 (improving existing)			Alt 4 (new infra)		
	share of increase in cycle trips attributed to cycle highway			share of increase in cycle trips attributed to cycle highway		
	4%	20%	40%	4%	20%	40%
cost (M Eur)	2.9	2.9	2.9	20.25	20.25	20.25
benefit (M Eur)	5.1	25.7	51.4	5.1	25.7	51.4
benefit/cost	**1.8**	**8.9**	**17.7**	**0.3**	**1.3**	**2.5**

Table 0.1: Overview of costs and benefits for two cycle highway scenarios

The green columns represent an intermediate scenario with a 7% in cycling modal share in 2035, as foreseen in the Luxembourg mobility plan (Ministère de la Mobilité et des Travaux publics luxembourgeois, 2022). The intermediate scenario estimates furthermore that 20% of cyclist users are there thanks to the cycle highway. The other 80% would have cycled anyway and their benefits are not taken into account.

Based on these hypothesis, **benefits are 8.9 times higher than the costs when upgrading the existing infrastructure** (alternative 2) for 100 000 EUR/km. **Benefits are 1.3 times higher if a new infrastructure (alternative 4) is built** at a cost of 750 000 EUR/km. Benefits are **mainly health benefits**, approximately 75%.

Figure 0-3 illustrates the benefits and costs for the upgrade alternative with 4%,20% or 40% of the increase in cycle km attributable to the cycle highway. This corresponds to the left hand side part of Table 0.1. The graph makes it also visually clear that benefits surpass costs.

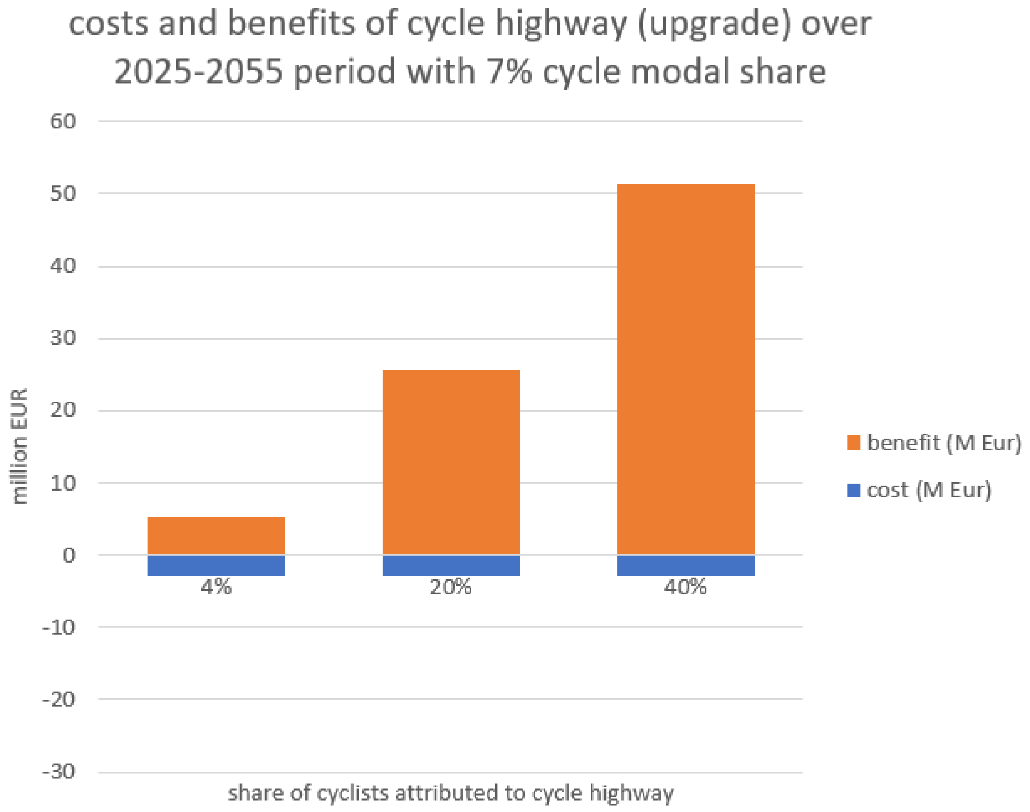

Figure 0-3: Costs and benefits of building the cycle highway (upgrade)

Results are robust, especially for the upgrade of existing infrastructure

The table shows that the benefits of the upgrade alternative (alt 2) remain 80% higher than the costs, even if only 4% of the cycle highway users are considered as being there, thanks to the cycle highway. This is however not true for the building of new infrastructure where costs (20.25 M EUR) surpass benefits (5.1 M EUR) in that case.

Other sensitivity analyses show that with a cost of 100 000 EUR/km for the upgrade, and with only 4% of the new cyclists, the cycling modal share needs to reach only 4.2% instead of 7% in 2035 to have benefits that are larger than the costs. Furthermore, with a cost of 100 000 EUR/km, and with 20% of the increase in cyclists that is attributed to the cycle highway, a 1.5% modal share is sufficient to generate benefits larger than costs.

Transparent hypothesis to realise the risks for over- or underestimation

The main assumptions, based on literature, used for our analysis besides those mentioned above are:

- Average distance of a cycle trip on the cycle highway: 8km
- Shares of different bicycles: 65% push bikes, 35% of e-bikes
- Shares of other modes that cyclists would use in the absence of the cycle highway; 25% would drive a passenger car, 45% would use public transport, 5% would walk, 10% would not have made the journey. 15% cycle already

- Costs and benefits of the different modes are based on the first part of the study

All sources are provided in the report.

Policy recommendations

The results of this study lead to the following policy recommendations, which are discussed in detail in the report:

1. Invest in safer, faster and more convenient cycling infrastructure,
2. Reduce the private costs of cycling,
3. Build and maintain the Arlon-Luxembourg cycle highway,
4. Create a cycle-friendly attitude and environment,
5. Develop multimodal bicycle-inclusive mobility plans,
6. Leave nobody behind, work on the image of cycling.

1 Context and scope

KEY TAKEAWAYS

Several studies show that **cycling leads to significant social benefits**. To date, no study exists that covers the Benelux-NRW region as a whole.

All national cycling plans in the Benelux-NRW demonstrate great ambitions **to increase cycling activity** in the region.

Effective promotion of cycling requires its inclusion in multiple policy domains. In The Netherlands cycling is an integral component of long-term policy plans such as the Dutch Climate Policy, national and local health plans and urban development plans.

1.1 Costs and benefits of cycling – state of the art

For policy makers and mobility planners, it is crucial to understand the costs and benefits of different transport modes to society. Several studies compute the societal impact of a specific transport mode in a specific region or country. However, to our knowledge, no study exists that calculates the costs and benefits of various transport modes in different countries or regions. For the sake of comparability and to make decisions on cross-border mobility initiatives, such analysis is imperative. This is exactly what this study aims to achieve.

We first discuss the findings of other cost-benefit analyses (CBA, henceforth) on cycling in the Benelux and North Rhine Westphalia.

Decisio (2014) makes a CBA of cycling compared to travelling by passenger car or bus in the Netherlands. They find that although the private costs of cycling are higher than for the other transport modes, cycling has the lowest overall costs thanks to its positive effects on society. The higher private costs of cycling are mainly caused by the time costs resulting from a lower travel speed. The external benefits of cycling sprout predominantly from health benefits. Passenger transport by car leads to costs to the society. These arise mainly from congestion, air pollution and accidents.

Table 1.1 Total costs and benefits of three transport modes in the Netherlands (€/pkm)

	Bicycle	**Car**	**Bus**
Private effects	-€ 0.67	-€ 0.58	-€ 0.53
External effects	€ +0.68	-€ 0.37	-€ 0.29
Total costs (-) and benefits (+) in €/pkm	**€ +0.01**	**-€ 0.95**	**-€ 0.82**

Source: Decisio (2014)

In a study for Utrecht, Decisio (2017) estimates the external benefit of cycling in an urban environment at € 0.5/km, which is somewhat lower than the external effect reported in Table 1.1 based on their study for the Netherlands.

A study by the GD Luxembourg reports that one cycling kilometre leads to an external cost of 5.2 eurocents to society. The main determinant of this cost are accident costs. At the same time, cycling results in an external benefit of 12.11 eurocents per kilometre. These benefits result from a reduction of expenses on public health care.[6] Table 1.2 shows the external costs and benefits of different passenger transport modes in Luxembourg. Note that the numbers is Table 1.2 are significantly lower than the external effects that are reported for the Netherlands in Table 1.1. It is difficult to determine the source of this difference. It can be due to different valuation techniques or because of a different number of effects that was taken into account. Table 1.1

Table 1.2 External costs and benefits of passenger transport in Luxembourg (€/pkm)

	Bicycle	Car	Bus	Train
External costs	-€ 0.05	-€ 0.03	-€ 0.03	-€ 0.03
External benefits	€ 0.12	€ 0.00	€ 0.00	€ 0.00
Total external costs (-) and benefits (-)	€ 0.07	-€ 0.03	-€ 0.03	-€ 0.03

Bouwen et al. (2022) compute the costs and benefits of current and potential cycle policies in Belgium. They find that current cycling activity in Belgium leads to a net social benefit of € 8.44 billion. This social benefit is mainly contributed to health benefits under the form of the prevention of premature death. An increase in cycling activity in line with the expectations of the Federal Planning Bureau (i.e. +17.5% in distance travelled by 2030), would yield and additional social cost saving of € 584 per year.

1.2 Current policy incentives for cycling

The different Benelux-NRW regions and countries have all their cycling policies, cycling plans and incentives for cycling. Below we provide some of these initiatives without being exhaustive.

National Cycling Plans

- In Germany, the **National Cycling Plan 3.0 (NCP3.0)** has the ambition to transform to country into a cycling nation. By 2030, the NCP3.0 foresees a significant increase in cycling mileages. More specifically, the cycling activity is expected to double by 2030 compared to 2017. This increased activity will be the result of both more cycling trips per person (from 120 to 180 trips per person per year), and longer distances travelled (from 3.7 km on average to 6 km on average per trip).
- The Belgian government has developed the **Be Cyclist Action Plan** that contains several action points from 2021 to 2024 to stimulate a regular use of the bicycle. The Federal Planning Bureau predicts increase in cycling kilometres of 17.6% by 2030 compared to 2019. By 2040, cycling activity will be 35.2% higher than in 2019 (Daubresse et al., 2022). The projections by the Federal Planning Bureau are based on current cycling policies and don't take future actions as determined in the Be Cyclist Action Plan into account.
- In Luxembourg, a key role to cyclists is given in the **National Mobility Plan 2035 (PNM 2035)**. The PNM 2035 has the objective to drastically increase the modal share of cycling through integrating high-quality cycling infrastructure in all road projects. Compared to a cycling activity of 36,000 trips per year in 2017, the PNM 2035 has the ambition to achieve 274,000 cycling trips by 2035, which corresponds to an increase of over 600%. This this requires a drastic behaviour change in Luxembourg. Given the current low modal shares of cycling in the country (see Section 2.2), there is potential in Luxembourg to obtain a strong increase in cycling activity, provided that appropriate incentives and flanking measures are implemented.

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[6] https://transports.public.lu/fr/contexte/situation-actuelle/chiffres-cles.html

- **National Cycling Vision of the Future** is a product by the Tour de Force. It presents the measures and investments needed to further stimulate cycling in the Netherlands. As a consequence of cycling stimulating policies such as a dense cycling infrastructure network and multi-modal initiatives, the report predicts that cycling kilometres in the Netherlands will increase with 20% by 2027 compared to 2017. By 2040 cycling kilometres are expected to exceed the 2017 values by 40%.

Dedicated Cycling Policies and Initiatives

The Netherlands stands as a best practices example with respect to an **integrated cycling policy** with a **long-term vision**.

Cycling policies in the Netherlands are embedded in the housing policy, mobility and infrastructural policy, vulnerable groups (elderly -mobility poverty) policy and health policy. Examples of these bicycle inclusive policies are the following:

- The Netherlands will build 1,000,000 houses by 2030. These needs to be accessible and therefore € 7.5 billion is foreseen for mobility solutions including bicycle solutions.
- For the elderly, (electric) bicycle training will reduce accidents but is also an instrument again social isolation and loneliness.

The development of such an integrated cycling policy sprouts from a group of cyclist volunteers, Friends of Cycling, working in the different administrations and meeting informally in order to not forget the bicycle in the different policy domains.[7]

Another initiative in the Netherlands is the "**bicycle ambassador-project**". This refers to employers that act as ambassadors to promote cycling among their employees and colleague employers. Ambassador employers are active in different economic sectors and promote cycling for commuting among their employees but also among their colleague employers.

In North Rhine-Westphalia (NRW), a cycle law is in place aiming at a 25% cycling modal share in NRW. Regular evaluation needs to enable public authorities to take stricter measures in order to reach the target.[8]

Also in NRW, a partnership for cycle friendly localities exists. Several localities join forces in order to promote cycling on their territory.[9]

Because the purchase cost of e-bikes and speed pedelecs may be a barrier to their further uptake, several countries including the Netherlands and Belgium provide **tax-friendly bike leasing schemes**. Under such a scheme, a bicycle can be leased from the employer at a very low charge. If the bicycle is used for commuting to work, the benefit is exempt from taxes, even if the bicycle is also used for private purposes.

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[7] https://www.rijksoverheid.nl/actueel/nieuws/2022/07/19/kabinet-schakelt-tandje-bij-voor-meer-mensen-op-de-fiets

[8] https://recht.nrw.de/lmi/owa/br_bes_text?anw_nr=2&gld_nr=9&ugl_nr=99&bes_id=47228&menu=0&sg=0&aufgehoben=N&keyword=Fahrrad#det0

[9] https://www.agfs-nrw.de/

1.3 Current cycling highways

Every country and regions in the Benelux-NRW region has its own dedicated cycle highway policy. They start generally with a potential analysis and choose the most promising connections. The map with built, planned or projected cycle highways in The Netherlands, NRW and to a lesser extent Luxembourg (country) illustrates this approach. Wallonia also invests in cycle highways to connect Wallonia with Brussels on two dedicated stretches.[10]

The approach in Flanders is different as the aim is to have a cycle highway network that covers the whole territory. The Flanders map illustrates it as well.

Figure 1-1 Map of the cycle highway network in the Netherlands

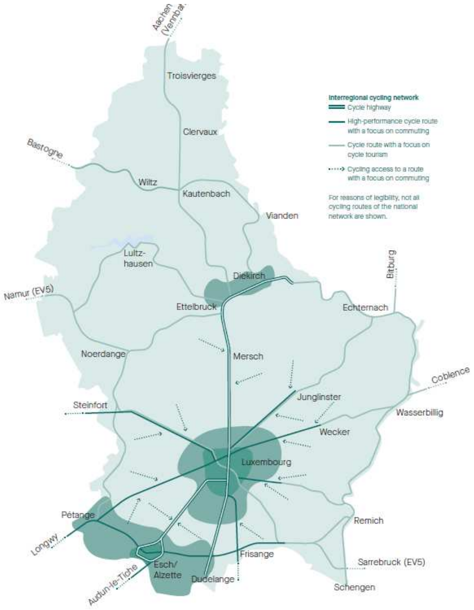

Figure 1-2 Map of the cycle highway network in Luxembourg

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[10] https://henry.wallonie.be/home/communiques-de-presse/presses/n275-et-e411--developpement-des-corridors-cyclables.html

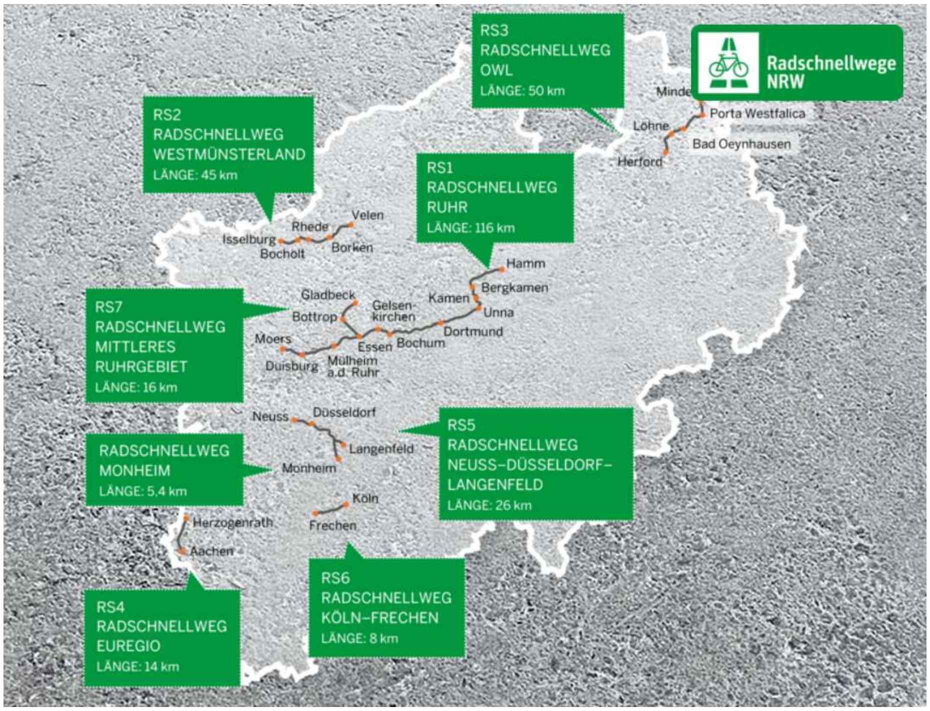

Figure 1-3 Map of cycle highways in NRW

Figure 1-4: Cycle highway network in Flanders

2 Cycling in the Benelux and NRW – facts and figures

KEY TAKEAWAYS

Per 100 citizens, the Benelux-NRW has 78 push bikes, 12 e-bikes and 0.3 speed pedelecs. Bicycle ownership is the highest in the Netherlands and the lowest in Belgium, where regional differences are large. The share of e-bikes in the total bicycle fleet increases over time.

The **modal share of cycling in all passenger trips differs considerably across the regions**. The Netherlands is a true cycling country where 27% of all trips are covered by bicycle. Belgium and NRW have a modal share of 12% and 11% for cycling. Cycling activity is the lowest in Luxembourg, where only 2% of all trips were covered by bike in 2017.

In this chapter we provide some key figures regarding cycling activity and the bicycle fleet in the Benelux and North Rhine-Westphalia (NRW). Where possible, we make a distinction between push bikes, e-bikes and speed pedelecs.

2.1 Bicycle fleet

The Netherlands is renowned for its high number of cyclists. This is confirmed by our statistics that show the highest number of bike ownership per 100 citizens in the Netherlands (Table 2.1). Unfortunately, we have no regional specific numbers on the bicycle fleet in NRW. Therefore, the numbers for this region show country-wide statistics for Germany.

Table 2.1 Bicycle fleet, 2021

	BE	**DE**	**LU**	**NL**
Push bike	7 759 451	NA	418 000	20 874 477
E-bike	2 353 412	7 100 000	86 000	2 500 000
Speed pedelec	44 758	NA	1 000	25 523
TOTAL	**10 157 621**	**72 000 000**	**505 000**	**23 400 000**
Bike ownership per 100 citizens				
Push bike	43.9	NA	66.3	122.8
E-bike	12.4	8.6	13.7	14.7
Speed pedelec	0.4	NA	0.2	0.2
TOTAL	**56.7**	**86.7**	**80.2**	**137.6**

Source: Own calculations based on Fietsberaad, deutschland.de, transports.public.lu, BOVAG, CBS.

Overall, bike ownership is the lowest in Belgium, but there are large difference in the bicycle fleet across the regions. In Flanders, bicycle ownership is very high, similar to the numbers for the Netherlands. This is especially the case for e-bikes and speed pedelecs. 95% of all speed pedelecs in Belgium are registered in Flanders.

Table 2.2 Bicycle fleet by region in Belgium, 2021

	BE - TOTAL	FLA	WAL	BRU
Push bike	7 759 451	5 822 549	1 562 298	374 604
E-bike	2 353 412	2 153 545	170 089	29 777
Speed pedelec	44 758	42 848	1 036	875
Bike ownership per 100 citizens				
Push bike	43.9	88.2	43.4	31.2
E-bike	12.4	32.6	4.7	2.5
Speed pedelec	0.4	0.6	0.0	0.1
TOTAL	**56.7**	**121.5**	**48.2**	**33.8**

Source: Own calculations based Fietsberaad, DIV, Statbel

For the Benelux-NRW as a whole, there are on average 78 push bikes, 12 e-bikes and 0.3 speed pedelecs per 100 citizens (Figure 2-1).

In the total bicycle fleet, e-bikes and speed pedelecs currently represent a relatively modest share. However, when we look at their share in new bicycle sales, this will probably change over time. Especially e-bikes have become very popular. In Belgium and the Netherlands, e-bike sales represented nearly half of all new bike sales in 2020.[11,12] In 2021, the growth of the e-bike segment slowed down to some extent. Traxio reports the share of e-bike sales in total bike sales at 39% for Belgium.[13]

Figure 2-1 Bike ownership in the Benelux-NRW

2.2 Cycling activity

There are significant differences between the four countries with respect to cycling activity. Table 2.3 shows the modal shares of passenger travel in the different countries/regions. The data is obtained from mobility surveys in the respective regions in 2017. Cycling activity is the most prominent in the Netherlands, where 26% of all trips are done by bike. The bicycle is least used in Luxembourg, where cycling represented only 2% of all trips in 2017.

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[11] https://www.traxio.be/nl/artikels/bijna-600-000-nieuwe-fietsen-verkocht-in-2020-sterke-stijging-elektrische-fietsen/

[12] https://electrek.co/2021/03/18/the-country-where-half-of-all-bicycles-sold-are-electric-bikes-and-what-it-can-tell-us/

[13] https://www.traxio.be/media/mpwpdog4/le-march%C3%A9-belge-du-v%C3%A9lo-en-2021-digital.pdf

Table 2.3 Modal share of trips per passenger transport mode in 2017

	BE	NRW	LU	NL
Passenger car (driver)	45%	43%	69%	29%
Passenger car (passenger)	16%	14%		13%
Public transportation	11%	10%	17%	6%
Bicycle	**12%**	**11%**	**2%**	**26%**
Walking	14%	22%	12%	23%
Other	2%	0%	0%	3%

Source: FOD Mobiliteit en Vervoer (2019), Follmer and Grunschwitz (2019), Ministère du Développement durable et des Infrastructures (2017), Kennisinstituut voor Mobiliteitsbeleid (2019)

Based on the modal shares of total person kms of passenger transport and the total bicycle fleet, we can calculate the average mileage per year for a cyclist. According to Crow (2013), the distance covered by an e-bike is on average 1.7 times higher than that covered by a push bike. For speed pedelecs, this difference is even bigger. A survey by Fietsberaad (2020) among Belgian speed pedelec riders reports that the average trip length covered is equal to 25 km. This is 4.2 times the average distance covered by a trip by a push bike as reported by FOD Mobiliteit en Vervoer (2019).

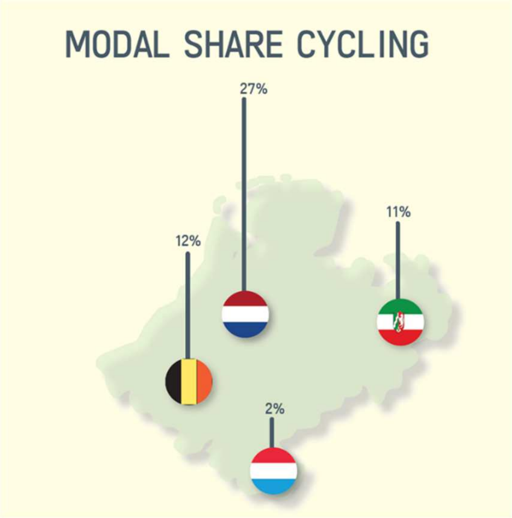

Figure 2-2 Modal share of cycling in the Benelux-NRW (data for 2017)

For Belgium, bike mileages are derived from the Monitor national mobility survey (FOD Mobiliteit en Vervoer (2019)). On average, Belgians make 0.26 trips per day of about 6 km in length on a push bike. This corresponds to 565 km per year. Assuming that e-bikes and speed pedelecs have a mileage that is respectively 1.7 and 4 times higher than a push bike, we estimate 964 km per year by e-bike and 2260 km/year by speed pedelec.

In Luxembourg, bike riders covered on average 545 km per year in 2017 (Luxmobil, 2017). Applying the same scaling factors to the other bicycle types, an e-bike rider covers 927 km and a speed pedelec rides 2,180 km per year.

According to the CBS, a cyclist in the Netherlands covered 1 098 km on average in 2019.[14] This number contains the distance covered by all type of bikes. According to BOVAG and CBS, about 10.7% of the bicycle fleet are e-bikes and 0.1% are speed pedelecs. Hence, the average km per year driven by a push bike, e-bike and speed pedelec in the Netherlands is respectively 1 018 km, 1 731 km and 4 074 km.

Unfortunately, we do not have specific numbers for North Rhine Westphalia (NRW). Therefore, we rely on overall figures for Germany. According to the National Cycling Plan, there are 112 million kms ridden by bicycle in Germany per day. Over a total cycle fleet of about 72 million

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[14] https://www.cbs.nl/nl-nl/visualisaties/verkeer-en-vervoer/personen/fietsen

bikes,[15] this corresponds to 568 km per bike per year. Using the weighting factors for e-bikes and speed pedelecs, we assume a yearly mileage of 966 km per e-bike and 2 272 km per speed pedelec in Germany.

Table 2.4 Yearly mileage per bike rider and region

Yearly km	**BE**	**LU**	**NL**	**NRW**	**Average**
Push bike	565	545	1018	568	**709**
E-bike	961	927	1 731	966	**1 206**
Speed pedelec	2 260	2 180	4 074	2 272	**2 838**

Source: Own calculations based on CBS, FOD Mobiliteit en Vervoer (2019), Follmer and Grunschwitz (2019).

2.3 Purpose of cycling

A bicycle can be used for commuting or other transport trips, but also for leisure purposes such as sports or tourism. In a study for the Netherlands, Harms and Kansen (2018) report that 37% of all bicycle kilometres are travelled for leisure purposes. Commuting trips represent 24% of all biking kilometres, while education counts for a share of 20%.

Monitor (2019) provides insights in the travel motives in Belgium. The study makes a distinction between push bikes and e-bikes and shows that the motives to ride these bike types are somewhat different. While 23% of the trips by a push bike are used for commuting or business trips, the share of commuting and business trips is equal to 38% for e-bikes. Trips from and to school or other educational institutes represent 23% of all push bike trips, while this is only 7% for e-bike trips. Most children and youngster ride push bikes rather than e-bikes, which explains this difference.

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[15] https://www.deutschland.de/en/topic/life/sports-leisure/germany-land-of-bicycles#:~:text=Germans%20own%2072%20million%20bicycles,million%20inhabitants%20has%20a%20bike.

3 Cost and benefits of cycling versus other modes

In this chapter we quantify and monetize the costs and benefits of cycling in the Benelux-NRW region. We distinguish between **private costs and benefits** to cyclists, and costs and benefits to others, called **external costs and benefits**. The total costs to society, the **social costs**, are the sum of private and external costs. These costs and benefits are then compared to those of alternative transport modes, notably driving a passenger car or using public transportation.

KEY TAKEAWAYS

In this cost-benefit analysis, we take into account the following elements for each passenger transport mode: total costs of ownership (TCO), private time costs, congestion costs, greenhouse gas emissions and air pollution, health benefits, accident costs, noise costs, infrastructure costs and the occupation of public space.

A **bicycle is cheaper to purchase and operate than a passenger car**. Total costs of ownership for a bicycle range between 16 and 28 eurocents per kilometre, while an average passenger car costs easily 32 eurocents per kilometre. Bicycles can play a key role in **inclusive mobility policies**.

In general, a bicycle travels at a **slower speeds** than other transport modes, resulting in **relatively high time costs** for the user. However, this is not always true in an urban and/or congested environments. Several studies show that in cities, bikes move faster than cars.

The Benelux-NRW suffers from severe congestion, especially in peak hours. Congestion causes high economic costs. Bicycles do not contribute to congestion. Therefore, **a modal shift to cycling saves congestion costs and leads to large economic benefits**. **Every person that cycles to work instead of taking the car** for a 7 km (one-way) commuting trip in an **urban area** saves **€ 1 251 per year** in congestion costs only. In **rural areas** these congestion cost savings are equal to **€ 936 per person per year**.

Cycling contributes to public health. It reduces the risk of serious diseases and early death. As a result, regular cycling leads to savings in social security spending. The most significant health benefit from cycling are the **productivity gains by people who cycle to work regularly**. Cycling commuters report 1.3 less sick days per year. For the Benelux-NRW this represents **an economic gain of € 2.9 billion per year**.

Apart from these main effects, cycling results in several other positive effects to society compared to other modes of passenger transport. Cycling does not emit CO_2 or other air pollutants and a bicycle is silent. Cycling infrastructure is cheaper to build and maintain and uses less public space than other passenger transport infrastructure. In addition, areas that enable cycling are more pleasant living environments.

Cycling comes with a higher accident risk than other transport modes. Therefore, to reap the important benefits that come with cycling, **improving traffic safety should be a top one priority**.

3.1 General figures and assumptions

The cost-benefit analysis relies on specific assumptions with respect to vehicle attributes, driver and rider behaviour and speed.

3.1.1 Occupancy rates

To make costs and benefits comparable across transport modes, we express all cost and benefits in euro per person kilometre (€/pkm). This means that we have to convert costs per vehicle into costs per person based on the occupancy rate of the transport mode.

The occupancy rates per transport mode shown in Table 3.1 are obtained from the respective mobility reports or surveys in each country. For trains, we did not find country specific data. Hence, we apply a similar occupancy rate in each country based on Delhaye et al. (2017)

Table 3.1 Occupancy rates per transport mode

	BE	LU	NL	NRW
Bicycle	1.0	1.0	1.0	1.0
Passenger car	1.35	1.20	1.41	1.50
Bus	10.7	10.5	10.3	20
Train	250	250	250	250

Source: FOD Mobiliteit en Vervoer (2019), Follmer and Grunschwitz (2019), Ministère du Développement durable et des Infrastructures (2017), Kennisinstituut voor Mobiliteitsbeleid (2019)

3.1.2 Average speed

A vehicle's speed depends on its capacity, but also on traffic conditions (time of the day) and, type of road infrastructure and the area (urban versus rural). We base our assumptions regarding average speed per vehicle type on earlier studies (Decisio, 2014; Decisio, 2017; Delhaye et al., 2017).

The speed reported in the table below are averages from different studies in the Benelux-NRW area. For cars, we considered the speed for short-distance trips (up to 20 km). For long-distance trips, the average speed by car will be higher because of the larger proportion of primary roads. However, long-distance trips are not considered substitutable by bicycle.

Table 3.2 Average speed (km/h) per vehicle type

	Average speed (km/h)
Push bike	16
E-bike	20
Speed pedelec	30
Passenger car	35
Bus	30
Train	60

Sources: Delhaye et al. (2017), CBS, Fietsberaad (2020), Mobiel 21(2014), Epstein (2010)

3.1.3 Average lifetime

The private costs of ownership are largely dependent on the lifetime of the bike and the annual mileage of the user. We assume the **average lifetime for a push bike equal to 10 years**. Several sources mention that the lifetime of an e-bike is shorter than that of a push bike because the bike's battery, which comprises the majority of the cost, only lasts up to eight years.[16] Therefore, we set the **lifetime for e-bikes and speed pedelecs to 8 years**.

For passenger cars, we assume an average lifetime of 15 years.

3.1.4 *Annual mileage*

The annual mileage differs considerably across the regions under consideration. For the sake of comparison, we assume average yearly mileages as reported in Table 2.4. More specifically, **we assume the average mileage of a push bike to be 709 km per year. For an e-bike we consider 1 206 km per year and speed pedelecs are assumed to ride 2 838 km per year**.

Our assumptions for e-bikes and speed pedelecs are based on previous research that shows that **e-bikes ride on average 1.7 times longer distances** than push bike riders (Crow, 2013). This number is somewhat lower than the findings of a Norwegian study, that concludes that biking kilometres doubled when people replaced a conventional bike by and e-bike (Fyhri et al., 2016). The German National Cycling Plan 3.0 reports that average trips by e-bike were 1.65 times longer than average trips by push bike in 2017.

For speed pedelecs, we refer to the study by Fietsberaad (2020) that shows that the average distance covered by **a speed pedelec is four times higher** than that on a push bike.

3.1.5 *Price level*

All costs and benefits are expressed in constant price for the year 2022, based on the Harmonised Index of Consumer Prices (HICP) at the end of March, 2022.[17]

3.2 Private versus external costs and benefits

Total social costs and benefits of a transport mode comprise private elements and external effects. **Private costs and benefits** are those that apply exclusively to the user of the transport mode. We distinguish the following user-specific costs and benefits:

- Costs of ownership
- Time costs of the user
- Health benefits
- Accident costs

If someone uses a particular transport mode, the rider/driver may also cause effects to society, which are typically not taken into account by the transport user. Examples are the emission of CO_2 by cars and buses, the contribution to traffic congestion and the creation of traffic noise. These effects are called **external costs and benefits**.

We consider the following external effects caused by the use of a bicycle, passenger car, and public transportation:

- Congestion
- Greenhouse gas emissions and air pollution

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[16] https://www.ebikebond.nl/hoe-lang-gaat-een-elektrische-fiets-mee/
https://www.anwb.nl/fiets/onderhoud/snelst-slijtende-fietsonderdelen
https://electricbikereport.com/how-long-do-electric-bike-batteries-last/

[17] https://www.ecb.europa.eu/stats/macroeconomic_and_sectoral/hicp/html/index.en.html

- Accidents
- Noise
- Health benefits
- Occupation of public space and quality of the living environment
- Infrastructure costs

In the following sections, we discuss each of the private and external costs and benefits individually.

3.3 Costs of ownership

Private costs of ownership for cycling include the purchase costs, maintenance and repair costs and the use costs (electricity consumption of e-bikes and speed pedelecs) during the lifetime of the bicycle.

The total costs of ownership (TCO) are calculated over the lifetime of the bike. All costs are discounted to the present using the following formula:

$$TCO_T = UC + \sum_{t=1}^{T} \frac{RC_{i,t}}{(1+i)^t}$$

where UC represents the one-time upfront costs and RC are the recurrent costs over the lifetime T. The recurrent costs are discounted at a discount rate *i*, which is set at 1.5%. The TCO are then expressed in € per km by dividing the TCO by the mileage of the vehicle. We assume that the bike has no residual value at the end of its lifetime.

Purchase costs

We collect information on current purchase prices of bicycles per bike category. We assume that the purchase price is similar across the regions, but we take into account the different VAT rates in each country. Therefore, Table 3.3 reports **median purchase prices** for push bikes, e-bikes and speed pedelecs, excluding VAT. For push bikes, the median price is based on prices for a basic city bike, a premium city bike and a touring bicycle. E-bike prices are collected from E-gear, that published sale prices of the 20 most commonly sold e-bike models. Prices for speed pedelecs are from speedpedelec.org, where 11 different models are compared.

Table 3.3 Median purchase price (excl. VAT) in € 2022

	Purchase price
Push bike	€ 579
E-bike	€ 1 983
Speed pedelec	€ 3 471

Source: Fietserbond (push bike), Egear (e-bike), Speedpedelec.org (speed pedelec)

Speed pedelecs or e-bikes can also be leased from the employer. This reduces the costs for the user of the bikes significantly. A leasing scheme is not considered in the cost-benefit analysis. It corresponds to a shift of the private costs from the user of the bike to the employer, so it doesn't change the private costs of the bicycle.

The purchase of a bicycle typically involves the **purchase of specific gear** (for example reflective clothing or a helmet). Van Zeebroeck et al (2018) assume € 100 (excl. VAT) for gear and accessories. We convert this cost to prices for the year 2022 using the harmonized consumer price index. For speed pedelecs, we increase the cost for gear and accessories by 20% because a helmet is mandatory for speed pedelec riders, while it is only advised gear for other bikes. More specifically, we assume a purchase expense for gear and accessories equal to € 117 for push and e-bikes and € 140 for speed pedelecs.

In some countries or regions, owners of an e-bike or speed pedelec benefit from a **purchase subsidy**. In Luxembourg, a premium up to 50% of the purchase price the bicycle can be received, with a maximum of € 600 for e-bikes and push bikes and € 1 000 for speed pedelecs. In NRW and the Netherlands, premia exist for the purchase of (e-)cargobikes, not for bicycles intended for private use. Belgium does not offer a national purchase subsidy. However, some local initiatives exist. For example in Kortrijk, a bike purchase subsidy up to € 400 is granted if the bike purchase coincides with the scrappage of a car license plate. A similar car-for-bike exchange scheme exists in Brussels, with a premium up to € 505.

Maintenance, repair and insurance costs

TNO (2010) and Van Zeebroeck et al. (2018) report that annual expenses for maintenance and repair of push bikes and e-bikes is respectively € 50 and € 75 in Belgium and the Netherlands in 2010. Converted a price level for the year 2022, this corresponds to an annual cost of **€ 65 for push bikes and € 97 for e-bikes**. We apply these rates in all four regions.

Maintenance and repair costs for speed pedelecs are usually somewhat higher than for e-bikes. This is because some bicycle parts such as tires and brake pads wear down faster due to the bike's higher speed and weight.[18] Therefore, we assume a 10% higher **maintenance and repair cost for speed pedelecs,** notably **€ 107 per year**.

In most countries, riders of speed pedelecs are obligated to have a civil liability insurance. Annual insurance premia vary depending on the insurer, the age of the bike and the purchase costs. On average, we find that **insurance costs € 150 per year**. This costs is similar across the regions. In Belgium, a civil liability insurance is not obligated for speed pedelecs, although it is recommended.

Energy consumption

The battery of an e-bike and a speed pedelec needs regular recharging. The **energy consumption** of the bike depends to a large extent on the driving profile and the terrain. On average an e-bike consumes 0.483 kWh/100 km and a speed pedelec 1 kWh/100km.[19]

We use electricity prices paid by a medium-sized household as reported by Eurostat.[20] We take values for the year 2021. Electricity prices for the year 2022 are not considered representative because of the energy crisis caused by the Ukraine-Russian war.

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[18] https://www.ebikebond.nl/wat-kost-een-speed-pedelec/

[19] https://www.mijnenergie.be/blog/hoeveel-kost-het-opladen-van-een-elektrische-fiets/
https://speedpedelec.org/fietsaccessoires/speed-pedelec-accu/

[20] https://ec.europa.eu/eurostat/databrowser/view/ten00117/default/table

Table 3.4 Average electricity price (incl. taxes) household consumers 2021 (in €_2022)

	Electricity prices (€/kWh)
BE	€ 0.2994
DE	€ 0.3234
LU	€ 0.1989
NL	€ 0.1449

Source: Eurostat

Bicycle allowance

In several countries, employees enjoy a tax benefit in case they commute to work by bicycle. This is the case in Belgium, the Netherlands and NRW. In Luxembourg, there is no cycling allowance for commuters.

In 2022, the bicycle allowance (tax credit) is equal to:

- € 0.25/km in Belgium
- € 0.19/km in the Netherlands
- € 0.30/km in Germany

Table 3.5 shows the share of total kilometres by push bike, e-bike and speed pedelec that is used for commuting. The speed pedelec is most often used for commuting.

Table 3.5 Share of commuting-km in total km by bike, e-bike and speed pedelec

	BE	NL	NRW
push bike	21%	24%	23%
e-bike	35%	23%	29%
speed pedelec	73%	47%	60%

Source: FOD Mobiliteit en Vervoer (2019), CBS, van der Salm (2020). For NRW, percentages are the average of those for BE and NL

Note that not all employees can benefit from a bicycle allowance. For example, in Belgium a bicycle allowance is used by 89% of employees that cycle to work in Flanders, 76% in Brussels and 78% in Wallonia (FOD Mobiliteit en Vervoer, 2019).

TCO bike

Table 3.6 shows the private ownership costs of each bicycle category and per country. The total TCO shows the discounted value of all costs during the lifetime of the bicycle. For push bikes, we assumed a lifetime of 10 years, while for e-bikes and speed pedelecs a life of 8 years was assumed.

Table 3.6 Private ownership costs of cycling Benelux - NRW

Push bike	**BE**	**DE**	**LU**	**NL**
One time costs	€ 841	€ 827	€ 524	€ 841
Bicycle commuting allowance	-€ 326	-€ 420	€ 0	-€ 331
Fixed operating costs	€ 660	€ 660	€ 660	€ 660
TOTAL TCO	**€ 1 175**	**€ 1 068**	**€ 1 185**	**€ 1 171**
TCO €/km	**€ 0.17**	**€ 0.15**	**€ 0.17**	**€ 0.17**

E-bike	**BE**	**DE**	**LU**	**NL**
One time costs	€ 2 541	€ 2 499	€ 1 936	€ 2 541
Variable operating costs	-€ 753	-€ 748	€ 10	-€ 440
Fixed operating costs	€ 822	€ 822	€ 822	€ 822
TOTAL TCO	**€ 2 610**	**€ 2 574**	**€ 2 769**	**€ 2 923**
TCO €/km	**€ 0.27**	**€ 0.27**	**€ 0.29**	**€ 0.30**

Speed pedelec	**BE**	**DE**	**LU**	**NL**
One time costs	€ 4 399	€ 4 335	€ 3 275	€ 4 531
Variable operating costs	-€ 3 702	-€ 3 695	€ 48	-€ 3 515
Fixed operating costs	€ 2 178	€ 2 178	€ 2 178	€ 2 178
TOTAL TCO	**€ 2 875**	**€ 2 818**	**€ 5 500**	**€ 3 193**
TCO €/km	**€ 0.13**	**€ 0.13**	**€ 0.24**	**€ 0.20**

For push bikes, we find private ownership costs to be comparable across regions, ranging from € 0.15/km in NRW, to € 0.17/km in Luxembourg. Variable operating costs for push bike consists of the bicycle allowance, where relevant.

Private ownership costs for e-bikes are considerably higher than those for push bikes, ranging from € 0.26/km in NRW to even € 0.30/km in the Netherlands. This higher cost is mainly explained by the higher purchase price of an e-bike, combined with a shorter lifetime. For e-bikes and speed pedelecs, the variable operating costs consist of the bicycle commuting allowance (that represent a benefit) and the energy costs from recharging the battery. Luxembourg does not offer a bicycle commuting allowance. Hence, for Luxembourg variable operating costs only consist of recharging costs.

The ownership costs of speed pedelecs differ considerably across the regions. Ownership costs are the lowest in NRW and Belgium, notably € 0.12/km. In Luxembourg, owning and operating a speed pedelec is most expensive at € 0.24/km. The reason for this large difference is the commuting allowance. Because the speed pedelec is predominantly used for commuting, this allowance has a large impact on the TCO of speed pedelecs.

TCO passenger car

We compare the private ownership costs of cycling with those of a passenger car. We calculate the TCO for a commonly sold car model, the Volkswagen Golf, with a petrol engine, assuming a yearly mileage of 15,000 km and a holding period of 10 years. At the end of the holding period, the passenger car has a residual value of 23% of its purchase price. The residual value is calculated based on the total mileage of the car, following Steinbuch (2014).

Table 3.7 TCO of a petrol-driven car and annual mileage of 15 000 km

	BE	**LU**	**NL**	**NRW**
One time costs	€ 23 784	€ 23 698	€ 43 609	€ 23 726
Variable operating costs	€ 24 596	€ 23 402	€ 26 676	€ 26 008
Fixed operating costs	€ 7 469	€ 5 142	€ 9 448	€ 5 741
TOTAL TCO	**€ 55 849**	**€ 52 242**	**€ 79 734**	**€ 55 474**
TCO €/vkm	**€ 0.37**	**€ 0.35**	**€ 0.53**	**€ 0.37**
TCO €/pkm	**€ 0.28**	**€ 0.29**	**€ 0.38**	**€ 0.25**

When we compare the TCO of a passenger car with that of a bicycle, it is clear that cycling is much more affordable than driving a car. Over the lifetime of the vehicle, people spend on average € 60 825 on a passenger car, while a bike costs only € 1 150 (push bike) to € 3 959 (speed pedelec) over its lifetime. The lifetime costs of a speed pedelec are lower than its purchase costs because of the bicycle commuting allowance. Even if we take into account that the average lifetime of a passenger car is longer than that of a bicycle and that a passenger car can transport more than one person, the bicycle remains the cheapest transport mode.

Private travel costs public transport

To compute the private travel costs for public transport by bus or train, we divide the average price of a ticket by the average trip length. In Luxembourg, public transportation is free, so there are no private travel costs.

Table 3.8 Private cost per person km public transportation

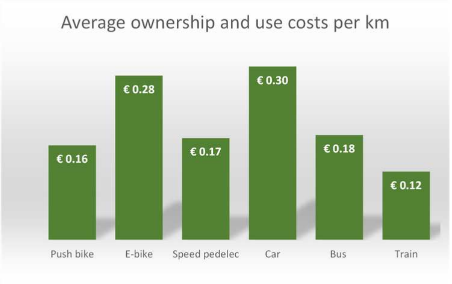
	BE	LU	NL	NRW
Bus	€ 0.25	€ 0.00	€ 0.18	€ 0.29
Train	€ 0.18	€ 0.00	€ 0.19	€ 0.10

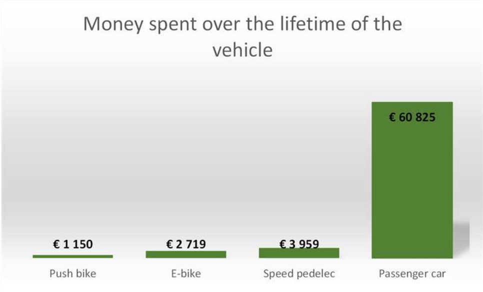
Sources: De Lijn, Vervoerregio.nl, Bahn.com

Summary – Total costs of ownership

A bicycle is cheaper to own and to operate than a car. The total costs of ownership range from € 0.16 per km to € 0.28 per person-km for a bicycle. Driving a passenger car costs you € 0.30 per km on average.

People spend on average € 60 825 over the lifetime of a car, while a bicycle costs only € 1 150 to € 3 959 over its lifetime. Even if we take into account the longer lifetime of passenger cars and the fact that a car can transport more than one person, cycling remains the cheapest mode of transportation.





3.4 Time costs

Apart from operating costs, transport users face time costs. Time costs reflect the opportunity costs of being able to do something else during the time of a trip. The "**value of time (VoT)**" reflects people's willingness to pay for travel time reduction.

There is an abundance of literature on the value of time. A recent and renowned study by the UK Department for Transport (DfT) estimates the value of time for different transport modes, distances and travel motives (Batley et al., 2019). Batley et al. (2019) make a distinction between different travel motives and distances to compute the value of time. We focus on the VoT for distances below 32 km, because this is the most applicable for bike travel. For trips shorter than 32 km, **VoT is equal to € 12.64/h for commuting and € 5.53/h for other travel motives**.

We calculate the VoT per country (region) and transport mode based on the share of travel motives as reported by respective mobility surveys. The private time costs are equal to the VoT divided by the average speed of each transport mode.

Table 3.9 shows the private time costs per transport mode in each region. Intuitively, time costs are negatively related to the speed of the transport mode. In general, time costs are the highest in Luxembourg. This is because in Luxembourg, the share of commuting trips in total travel is the highest.

Table 3.9 Value of Time (€/h) and private time costs (€/km, €_2022) per transport mode and country/region

	Push bike	E-bike	Speed pedelec	Car	Bus	Train
Value of time (€/h)						
BE	€ 7.02	€ 8.02	€ 10.73	€ 7.59	€ 7.45	€ 8.59
LU	€ 8.73	€ 8.73	€ 8.73	€ 8.73	€ 8.73	€ 8.73
NL	€ 7.24	€ 7.17	€ 8.87	€ 7.65	€ 7.47	€ 8.58
NRW	€ 7.13	€ 7.59	€ 9.80	€ 8.23	€ 7.47	€ 8.58
Speed (km/h)	16	20	30	35	30	60
Private time costs (€/pkm)						
BE	€ 0.44	€ 0.40	€ 0.36	€ 0.22	€ 0.25	€ 0.14
LU	€ 0.55	€ 0.44	€ 0.29	€ 0.25	€ 0.29	€ 0.15
NL	€ 0.45	€ 0.36	€ 0.30	€ 0.22	€ 0.25	€ 0.14
NRW	€ 0.45	€ 0.38	€ 0.33	€ 0.24	€ 0.25	€ 0.14

Source: Own calculations based on Batley et al. (2019), Decisio (2014), Delhaye et al. (2017), CBS, Follmer and Grunschwitz (2019), and Ministère du Développement durable et des Infrastructures (2017)

In per km terms, time costs for riding a speed pedelec are lower than those for the other bicycle types. This is because speed pedelecs are predominantly used for commuting, during which the value of time is higher than during other trips.

The average speed of a vehicle is different in urban and rural areas. This is especially the case for passenger cars. This is especially the case in cities with a lot of congestion, like Brussels and Luxembourg. Decisio (2017) reports that in urban areas, the average speed of a passenger car drops to 23 km/h. In highly congested areas, cars and buses travel at even lower speed. A study by Inrix showed that the average speed in Brussels was only 16 km/h in 2021.[21] When we assume an average speed of 23 km/h for passenger cars, average time costs for the Benelux-NRW urban environments increase to € 0.35 per passenger-km.

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[21] https://inrix.com/scorecard-city/?city=Brussels&index=3

Summary – Time costs

On average, a bicycle travels at **a slower pace** than other modes of passenger transport. This leads to **higher time costs** for the users. However, this is not always true in urban environments, where bicycles may move faster than cars.

Average time costs per passenger-km range from € 0.32 per person-km to € 0.47 per person-km for bicycle use. Driving a passenger car leads to € 0.23 km in time costs on average. **In urban environments, time costs for car use may be much higher**.
A train has the highest average speed, which leads to the lowest time costs. However, time lost due to delays or changing connections are not taken into account.

3.5 Congestion

Traffic congestion is one of the most challenging mobility concerns in the Benelux-NRW region. The problem is especially acute in urban areas. Brussels ranks third in the Inrix worldwide ranking of cities with the largest traffic delay.[22] But also The Netherlands, Luxembourg and NRW suffer from high congestion. During the COVID-2019 crisis in 2020, there was a brief period of more fluently flowing traffic. However, several studies demonstrate that current congestion levels are equal to or even above 2019 levels.[23]

Congestion costs are time costs that arise when transport users reduce the speed of other users of the transport system. They are considered as external costs. Marginal external congestion costs are the costs of one extra transport user that are borne by society, but that are not taken into account by the transport user him/herself. Given the high congestion problem in the Benelux-NRW, congestion costs in this area are large. The Federal Planning Bureau estimates the total social congestion for Belgium to be equal to 2.3 billion euro per year. This total social congestion cost consists of € 1.3 billion in time costs for road users (Hoornaert & Van Steenbergen, 2019).

Congestion costs are dependent on traffic conditions, road types and traffic volume. Especially in urban areas and during peak hours, external congestion costs can be very high.

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[22] https://inrix.com/scorecard/
[23] https://www.anwb.nl/verkeer/nieuws/nederland/2022/juli/dagelijkse-files-zijn-weer-terug

Table 3.10 shows the marginal external congestion costs for passenger cars and buses per country and level of urbanisation. The figures are obtained for EC DG MOVE (2020) and converted to prices for the year 2022.

Table 3.10 Marginal external congestion costs in €/pkm, prices for the year 2022

	BE	DE	LU	NL
	Passenger car			
Urban area	€ 0.41	€ 0.30	€ 0.65	€ 0.43
Inter-urban area	€ 0.31	€ 0.23	€ 0.49	€ 0.31
Average	€ 0.36	€ 0.26	€ 0.57	€ 0.37
	Bus			
Urban area	€ 0.06	€ 0.05	€ 0.11	€ 0.06
Inter-urban area	€ 0.08	€ 0.04	€ 0.08	€ 0.04
Average	€ 0.07	€ 0.04	€ 0.09	€ 0.05

Source: EC DG MOVE (2020)

For cyclists and train passengers, we assume the marginal external congestion costs to be equal to zero. This is a slightly underestimation of external congestion costs because in some cities congestion costs for cyclists do occur. However, data for these costs are unavailable. In any case, we assume these costs to be low because cyclists can manoeuvre between heavy traffic. As such they can minimize the impact of congestion on their travel speed.

Summary – Congestion costs

Each trip by **passenger car creates congestion costs** to society. Especially in densely populated areas, congestion costs are high. Each additional person-km covered by car leads to € 0.39 in congestion costs. **Cycling avoids these congestion costs**.

Every person that cycles to work instead of taking the car for a 7 km (one-way) commuting trip in an **urban area** saves **€ 1 251 per year** in congestion costs only. In **rural areas** the congestion cost savings are equal to **€ 936 per person per year**.

3.6 Greenhouse gas emissions and air pollution

Motorized traffic results in the emission of air pollutants and greenhouse gases. We make a distinction between the external costs of greenhouse gas emissions, which we call **climate change costs** and the external costs of **other air pollutants**. We only consider **direct emissions** (tailpipe emissions or tank-to-wheel emissions). Therefore, bicycles have a zero emission cost in this study. Note that the use of e-bikes and speed pedelecs cause indirect emissions, but these are not taken into account, neither are the indirect emissions from the other transport modes.

3.6.1.1 Climate change costs

Passenger transport results in the emission of greenhouse gases that contribute to global warming and climate change. There are large difference in the amount of greenhouse gases that are emitted per transport mode. Bicycles and electric vehicles are considered zero-emission.

To calculate the external climate change costs of each transport mode, we need two elements: (i) **the average amount of CO_2-emissions per vehicle type**, and (ii) **the external cost per unit CO_2-emissions**.

Table 3.11 shows the CO_2-emissions in gram per person kilometre for each passenger transport mode. For petrol, diesel and plug-in hybrid (PHEV) cars we assumed an average fuel consumption of respectively 7, 5.8 and 4.2 litres per 100 km. The CO_2-emissions shown in the table below differ across regions due to the different occupancy rates.

We calculate the average CO_2-emissions for passenger cars and buses in each country/region based on the composition of the vehicle fleet in 2021.

Table 3.11 CO_2-emission in g/pkm per passenger transport mode

	BE	**LU**	**NL**	**NRW**
Car petrol	124	140	119	112
Car diesel	113	128	109	102
Car PHEV	74	84	71	67
Car BEV	0	0	0	0
Bus diesel	110	112	114	59
Bus BEV	0	0	0	0
Train	26	26	26	26

Source: Own calculations and STIB-MIVB[24]

Table 3.12 Composition of the vehicle fleet, 2021

	Passenger Cars				**Bus**	
	Petrol	Diesel	PHEV	BEV	Diesel	BEV
Belgium	49.7%	46.2%	3.1%	1.0%	99.9%	0.1%
Luxembourg	42.9%	52.9%	3.1%	1.1%	92	8%
Netherlands	80.1%	12.5%	4.7%	2.7%	82.5%	17.5%
NRW	65.2%	31.2%	2.5%	1.1%	70%	30%

Sources: Statbel (BE), CBS and RVO (NL), ACEA (DE, LU)

The European Commission recently published and updated value for the cost of carbon that should be used in transport projects.[25] The cost of carbon measure the economic cost of meeting the emission reduction goal set in the Paris Agreement (the 1.5°C target). Figure 3-1 shows the evolution of this carbon cost for the period 2022 to 2030. We use the value for 2022 in our cost-benefit analysis, which corresponds to a carbon cost of € 133 per tonne CO_2 equivalent.

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[24] https://www.stib-mivb.be/article.html?_guid=008a3561-2ac1-3410-22bc-d575f8441615&l=nl#:~:text=Tram%3A%2030g%20CO2%20%2F(km,110g%20CO2%20%2F(km*passagier)

[25] Commission Notice — Technical guidance on the climate proofing of infrastructure in the period 2021-2027 (OJ C, C/373, 16.09.2021, p. 1, CELEX: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021XC0916(03))

As a result of the European Climate Laws of the European Commission, the share of battery electric vehicles (BEV) in the total vehicle fleet will increase considerably over time. This means that for the future years, the average CO_2 emissions of passenger transport in the EU countries should decrease. However, given the yearly increasing cost of carbon (Figure 3-1), this effect will largely be cancelled out.

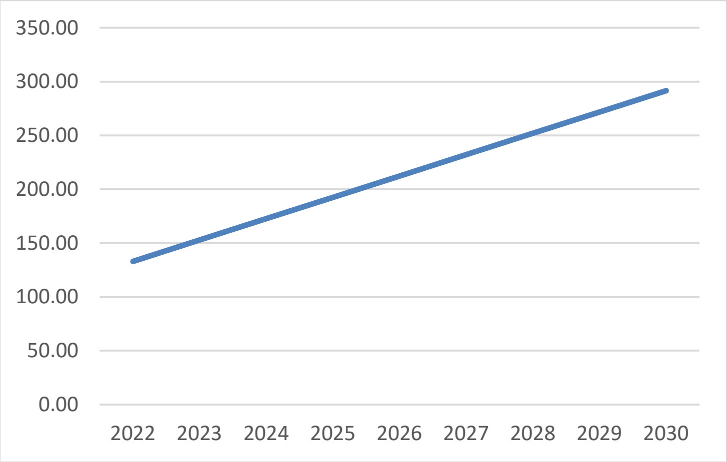

Figure 3-1 Shadow cost of carbon per year (in EUR_2022/tonne CO_2 eq)

The external climate change cost per person kilometre are the product of the average emissions per km and the carbon costs per km. The results are shown in Table 3.13.

Table 3.13 External cost of direct CO_2-emission per passenger transport mode (in €/pkm)

	Passenger car	Bus	Train
BE	€ 0.015	€ 0.015	€ 0.003
LU	€ 0.017	€ 0.013	€ 0.003
NL	€ 0.015	€ 0.012	€ 0.003
NRW	€ 0.014	€ 0.010	€ 0.003

3.6.1.2 Air pollution costs

Driving a passenger car or using public transportation leads to the emission of several air pollutants including fine particles (PM_{10}, $PM_{2,5}$), nitrogen oxides (NOx) and sulphur oxide (SO_2). Exposure to these pollutants causes negative health effects, crop losses, material and building damage and biodiversity loss.

DG MOVE (2020) calculates the average external air pollution costs for the following pollutants:
- NOX
- NMVOC
- SO2
- PM

We rescale these costs to prices for the year 2022 (Table 3.14). For railway passenger transport, we assumed all trains to be electric passenger trains, for which the air pollution costs are close to zero.

Table 3.14 Average air pollution costs in €/pkm (€_2022 prices)

	BE	LU	NL	NRW
Passenger car	€ 0.015	€ 0.022	€ 0.009	€ 0.009
Bus	€ 0.011	€ 0.022	€ 0.010	€ 0.013
Train	€ 0.000	€ 0.000	€ 0.000	€ 0.000

Source: EC DG MOVE (2020)

Summary - Emissions

Fossil fuelled passenger cars and buses emit greenhouse gases and other air pollutants. **Over its lifetime, an average car emits 35 tonne CO_2.** A bicycle emits no CO_2.

The expected electrification of the passenger car and bus fleet will significantly reduce CO_2-emissions, but non- CO_2 emissions of electric cars are as high and in some cases higher than those of fossil fuel cars (e.g. fine particles).

A bicycle has no direct emissions. **A modal shift from transport by car or bus to cycling avoids CO_2 emissions and contributes to clean air.**

3.7 Accidents

Traffic accidents result in material costs (damage to vehicles and/or infrastructure, administrative and medical costs) and immaterial costs (shorter lifetime, suffering, fear). The marginal social accident costs result from the increased accident risk caused by one additional kilometre travelled by a road user. Accident statistics show that cyclists are more vulnerable to serious accidents than users of passenger cars or public transportation.

For motorized traffic, we use the marginal external accident costs as reported by DG MOVE (2020), which provides accident costs on country level. Decisio (2017) reports the marginal accident costs for cycling in the Netherlands. For the other countries, there is no similar data available. We cannot apply the Dutch numbers to the other countries, because accident risk is regional-specific and depends on several local factors such as traffic intensity and quality of the infrastructure.

Table 3.15 shows the number of bicycle fatalities per country over the period 2017 to 2021. The accident risk is computed as the ratio of the total number of deceased and the total person kilometres (in millions). The risk of a deadly bicycle accident is the highest in Luxembourg and the lowest in the Netherlands and Germany. Belgium is in between. Note that the figures in Luxembourg are very sensitive to small changes because of the low absolute number in deadly accidents.

We calculate the social accident costs per bike-km in Belgium, Luxembourg and Germany by rescaling the Dutch costs by difference in accident risk in the respective countries. The result is shown in Table 3.16. Research shows that the accident risk and accident rate of e-bikes in not significantly different from that of push bikes (Verstappen et al., 2020; Petzoldt et al., 2017). Therefore, we use the same accident costs for push bikes and e-bikes. In most countries, speed pedelecs are considered as scooters. Therefore, accidents involving speed pedelecs are including in the statistics for scooters and mopeds.[26] We use the accident costs for scooters as a proxy for the accident costs of speed pedelecs. Note that this might be an overestimation of speed pedelec accident costs because in general, speed pedelecs move slower than scooters. Yet, the higher accident costs for fast e-bicycles is confirmed by other studies. For example, VeiligheidNL (2022) reports that the accident risk for e-bikes is 1.6 times higher than the accident risk for push bikes.

Following DG MOVE (2020), we consider that 70% of the accident costs are private costs and 30% are external costs.

Table 3.15 Bicycle accidents with fatalities 2017-2021

	2017	**2018**	**2019**	**2020**	**2021**	**TOTAL**	**Accident risk (per m pkm)**
Belgium	76	89	95	86	87	433	**0.013**
Germany	381	382	445	445	372	2 025	**0.008**
Luxembourg	0	3	0	3	0	6	**0.016**
Netherlands	206	228	203	229	207	1 073	**0.008**

Sources: Statbel, Destatis.de, CBS, Statc, SWOV

Table 3.16 Marginal social accident costs per country and transport mode (€_2022/prices)

	BE	**LU**	**NL**	**NRW**
Bicycles				
Push bike	€ 0.156	€ 0.191	€ 0.102	€ 0.096
E-bike	€ 0.156	€ 0.191	€ 0.102	€ 0.096
Speed pedelec	€ 0.226	€ 0.276	€ 0.147	€ 0.138
Passenger car	€ 0.058	€ 0.066	€ 0.036	€ 0.069
Bus	€ 0.008	€ 0.011	€ 0.006	€ 0.046
Train	€ 0.011	€ 0.029	€ 0.003	€ 0.016

Source: Decisio (2017), EU DG MOVE (2020) and own calculations

Summary - Accidents

Bicycle riders are considered **vulnerable road users**. This is confirmed by accident statistics, that show that accident risk is higher for bicycles than for passenger cars and users of public transportation.

Marginal social accidents costs for bicycles are more than twice as high than accident costs for passenger cars. Therefore, to reap the positive benefits of cycling, investing in traffic safety should be a main priority.

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[26] https://swov.nl/nl/fact-sheet/elektrische-fietsen-en-speed-pedelecs

3.8 Noise

As a result of a growing level of urbanisation, traffic noise is becoming more and more a source of disutility. Noise pollution leads to negative health effects such as hypertension and sleep deprivation. In addition, traffic noise causes annoyance costs, that increase with the noise level.

Noise costs arise as soon as someone is exposed to a noise level exceeding 65 dB. Social noise costs depend on the number of people exposed to noise above the 65dB threshold. EC DG MOVE (2020) computes the average noise cost per vehicle category and per country. For bicycles, we assume a zero cost because bicycles do not produce noise levels above the threshold level.

Table 3.17 Average noise costs in €/pkm (€_2022 prices)

	BE	LU	NL	NRW
Passenger car	€ 0.017	€ 0.006	€ 0.006	€ 0.004
Bus	€ 0.008	€ 0.003	€ 0.003	€ 0.002
Train	€ 0.016	€ 0.042	€ 0.005	€ 0.012

Source: EC DG MOVE (2020)

Summary - Noise

Bicycles are silent, in contrast to other passenger transport modes. Noise becomes a growing problem in urbanised environments. Noise pollution leads to negative health effects such as hypertension and sleep deprivation.

Increased bicycle use can contribute to a more quiet, enjoyable living environment.

3.9 Health benefits

Active transport modes like cycling and walking lead to health benefits. A cyclist experiences private health benefits. Cycling adds to an active lifestyle and helps to avoid diseases such as obesity and cardiovascular disorders. In addition to improved physical health, cycling brings positive mental health effects such as enjoyment, a clear head or fresh feeling and added attention (De Geus & Hendriksen, 2015; Van den Steen et al, 2019).

The health benefits from cycling do not only offer private benefits. **Society gains by each mile that is travelled by bicycle**. The health effects of cycling are threefold and consist of the following:

- First, cycling leads to better health which **avoids premature death** and/or leads to **an ameliorated quality of life**. This health effect is relatively hard to quantify and monetize because it reflects the value that people assign to a longer life and good health.
- Second, the health effects from cycling result in **savings on social security** expenses.
- Third, cyclists are less often ill and absent from work than non-active travellers. Therefore, regular cycling leads to **productivity gains** for employers.

The physical effort needed to ride a conventional bike is higher than an e-bike or speed pedelec. But because e-bikers ride longer trips compared to traditional cyclists, the physical activity gains are similar for e-bikers and riders of conventional bikes (Castro et al., 2019; De Geus & Hendriksen, 2015). In addition, e-bikes are also used by people in higher age groups, for whom the health benefits are most important. Some of those bikers would not cycle without an e-bike.

Health benefit 1: Reduced mortality and morbidity

In the literature, there are two methodologies to estimate the economic benefits from reduced mortality and morbidity rates: (i) the all-cause approach, and (ii) the morbidity impact approach.

The all cause approach estimates the health benefits of cycling by comparing two groups of people. The "test group" contains people that cycle on a regular basis, while the "control group" contains people who do not (or rarely) cycle. The impact of cycling is deduced from the different mortality rates between the control and the test group.

The morbidity impact approach estimates the health benefits from cycling based on simulations. The simulation model accounts for two aspects: disease prevention and the impact of cycling on these diseases.

The resulting economic health benefits from cycling differ considerably depending on the methodology chosen, the timeframe and the geographical focus. In a study for the U.K., Mc Donald (2007) estimates the health benefit at € 71 per cyclist per year.

Schepers and Wijnen (2015) apply the all-cause mortality method and the morbidity impact approach to evaluate the reduced mortality and morbidity benefits. For the all-cause approach, they use two different sources for the value of a statistical life, and estimate the benefits for the Netherlands in a range of € 0.38/km to € 1.29/km. Using the morbidity impact approach, the health benefits are estimated in a range of € 0.28/km to € 0.47/km.

In an evaluation of health benefits of cycling in Belgium, Delhaye et al. (2017) follow the study by Schepers and Wijnen (2015) and account for a € 0.38/km health benefit (values for the year 2016). In a cost-benefit analysis of cycling highways in Belgium, Beukers et al. (2015) compute the economic value of reduced mortality and morbidity at € 0.21/km (values for the year 2014).

We use the value from Delhaye et al. (2017) and convert this to prices for the year 2022. This means that **we value the benefit from reduced mortality and morbidity at € 0.44/km**. This value is assumed for a push bike. As shown in Chapter 2, e-bikes and speed pedelecs ride respectively 1.7 and 4 times more kilometers per year. Therefore, **the benefit from reduced mortality and morbidity is equal to € 0.26/km for and e-bike and € 0.11/km for a speed pedelec**.

Health benefit 2: Social security savings

The health benefits from cycling result in social security savings because people who cycle regularly are less frequently ill and live longer (in good health).

The precise amount of the reduction in social security expenses depends of the type of social security system in each country. For Belgium, we follow Van Zeebroeck et al. (2018) who determine the annual social security savings at € 85 per cyclist (assuming 936 km/year). This number is based on a study by De Smedt (2011) who calculates the impact of an active lifestyle on social security expenses. Converted to prices for the year 2022, this corresponds to a benefit of € 0.14/km for push bikes, € 0.08/km for e-bikes and € 0.03/km for speed pedelecs.

For the Netherlands, we use the values reported in the recent study by Decisio (2021). In this study, the impact of cycling on social security expenses is based on research by Ecorys (2017) that computes the expenses on public healthcare that can be avoided by an active lifestyle. Decisio (2021) computes the social savings benefit at € 0.20/km. However, this rate only applies for the 25% least active population. For the following 25% of the population (in terms of physical activity level) a benefit of € 0.10/km is computed. Decisio notes that for people who already have an active lifestyle irrespective of cycling, there is no benefit in social security savings. Therefore, we propose to use a value of **€ 0.10/km in social security benefits for the Netherlands** for riders of a push bike. For riders of e-bikes and speed pedelecs, we rescale the costs corresponding to the average yearly mileage of these bikes.

In Modu2.0 (2020), the external benefits from cycling under the form of a reduction in healthcare expenditure in **Luxembourg is determined at € 0.12/km** in 2016. The report doesn't provide details on the calculation method, but since we have no other source for this benefit for Luxembourg, we assume this value to be correct. We convert this value to prices of the year 2022.

No comparable data exists for NRW. Therefore, we use the average cost per km calculated for Belgium, the Netherlands and Luxembourg.

Health benefit 3: Productivity gains from lower absenteeism at work

Employees that commute to work by bicycle are fitter than people who don't cycle. This leads to lower absenteeism and therefore higher productivity. This is one of the reasons why employers stimulate an active lifestyle of their employees. A study by TNO (2010) shows that people who cycle to work regularly have on average 1.3 days less sickness absence than people that don't cycle. The same number of reduced sick days by cyclists is reported by Hendriksen et al. (2010). A Canadian study by the Alberta Center for active living estimates that labour productivity increases by 4 to 15 percent if employees engage in regular active movements.[27]

A recent study by Decisio (2021) assumes a maximum labour productivity gain of up to 3%. This maximum productivity gain assumes a daily cycling distance of 4.3 km (one-way), five days a week during 46 weeks. This corresponds to a yearly mileage of 1 980 km, which is in line with the yearly distance that we use for e-bike travel.

To calculate the societal cost of lower sick days, we need to know the average value of labour productivity in each country. We take labour productivity data (GDP per hour worked) from the OECD.[28]

The health benefits can be estimated based on two methods. The results of these calculation methods are shown in Table 3.18.

The **first method** follows the approach of Decisio (2021). We assume a productivity gain of cycling to work of 1% (which is in the lower range of what is assumed by Decisio). With 1 760 workable hours per year (8 hours per day times 220 working days), this corresponds to a yearly gain of 17.6

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[27] https://sites.ualberta.ca/~active/workplace/beforestart/benefits-bottom-line.html

[28] https://data.oecd.org/lprdty/gdp-per-hour-worked.htm#indicator-chart

labour hours. At the average value of labour productivity, this corresponds to a benefit per cyclist ranging from € 1 173 per year in Germany to € 1 944 per year in Luxembourg.

The **second method** starts from the finding by TNO (2010) that regular cycling results in 1.3 less sick days per year, or roughly 10 hours. Given the value for labour productivity, this results in a yearly benefit ranging from € 667 for Germany to € 1 105 for Luxembourg per cyclist.

Table 3.18 Value of productivity gains from cycling

	BE	LU	NL	NRW
Value of labour productivity (€/h)	€ 74.17	€ 110.48	€ 73.38	€ 66.66
Method 1				
Productivity gain per cyclist	**€ 1 305**	**€ 1 944**	**€ 1 291**	**€ 1 173**
Productivity gain per push bike km	€ 1.84	€ 2.74	€ 1.82	€ 1.65
Productivity gain per e-bike km	€ 1.08	€ 1.61	€ 1.07	€ 0.97
Productivity gain per s-ped km	€ 0.46	€ 0.69	€ 0.46	€ 0.41
Method 2				
Productivity gain per cyclist	**€ 742**	**€ 1 105**	**€ 734**	**€ 667**
Productivity gain per push bike km	€ 1.05	€ 1.56	€ 1.03	€ 0.94
Productivity gain per e-bike km	€ 0.61	€ 0.92	€ 0.61	€ 0.55
Productivity gain per s-ped km	€ 0.26	€ 0.39	€ 0.26	€ 0.23

Source: Own calculations based on OECD, Decisio (2021) and TNO (2010)

As a conservative approach, we use the results from the second calculation method to account for productivity gains. Hence, productivity gains from riding a push bike range from € 0.94/km to €1.56/km. Productivity gains from riding an e-bike range from € 0.55/km to € 0.92/km, and riding a speed pedelec leads to productivity gains between € 0.23/km to € 0.39/km.

Total health benefits of cycling

The total health benefits of cycling are equal to the sum of the three health effects. An overview is provided in the table below.

Table 3.19 Health benefits from cycling

	Belgium			**Luxembourg**		
	Push bike	e-bike	S-pedelec	Push bike	e-bike	S-pedelec
Reduced mort & morb	€ 0.44	€ 0.26	€ 0.11	€ 0.44	€ 0.26	€ 0.11
Social security savings	€ 0.14	€ 0.08	€ 0.03	€ 0.14	€ 0.08	€ 0.03
Productivity gains	€ 1.05	€ 0.61	€ 0.26	€ 1.56	€ 0.92	€ 0.39
Total health effect	**€ 1.63**	**€ 0.96**	**€ 0.41**	**€ 2.14**	**€ 1.26**	**€ 0.54**
	Netherlands			**NRW**		
	Push bike	e-bike	S-pedelec	Push bike	e-bike	S-pedelec
Reduced mort & morb	€ 0.44	€ 0.26	€ 0.11	€ 0.44	€ 0.26	€ 0.11
Social security savings	€ 0.10	€ 0.06	€ 0.03	€ 0.13	€ 0.07	€ 0.03
Productivity gains	€ 1.03	€ 0.61	€ 0.26	€ 0.94	€ 0.55	€ 0.23
Total health effect	**€ 1.58**	**€ 0.93**	**€ 0.39**	**€ 1.51**	**€ 0.89**	**€ 0.38**

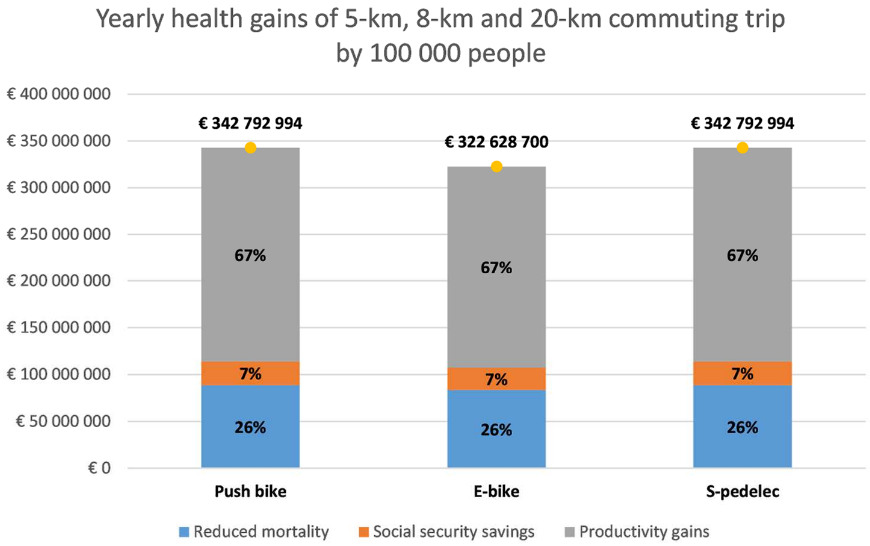
The majority of these health benefits are external benefits. Social security savings and productivity gains are considered external benefits. With respect to reduced mortality and morbidity, we follow Delhaye et al. (2017) and assume 30% of these benefits being private benefits.

Summary – Health effects

Regular cycling leads to three health benefits:

1. it **avoids premature death and serious diseases and leads to an ameliorated quality of life**,
2. it results in **savings on social security expenses**, and
3. it leads to **productivity gains.**

100 000 people that commute by push bike on a 5-km one-way trip,
100 000 people that commute by e-bike on a 8-km one-way trip,
100 000 people that commute by speed pedelec on a 20-km one-way trip,
generate a total social health benefit of **1 billion euro per year**. The majority of these health benefits consists of productivity gains.



3.10 Occupation of public space and impact on the environment

As a result of growing population numbers and rising urbanisation rates, public space has become a scarce resource. Transport modes and transport infrastructure take up space that can otherwise be used for alternative purposes such as housing or green areas.

Bicycles are very space-efficient, both in terms of static and dynamic space consumption (ITF, 2022). **Static space consumption** is the amount of space that is required for parking and vehicle storage. A single car parking spot can park up to 15 bicycles. **Dynamic space consumption** refers to the space that is occupied by moving vehicles. According to a study by the ECF, a 3.5 metres wide urban space can be crossed by 7 times more bikes than cars during a one hour timelapse (ECF, 2018).

In addition to the opportunity costs of the occupation of public space, exchanging road space for cars to cycling and pedestrian areas has an impact on the **quality of the environment**. People assign a higher value to streets with walking and cycling spaces (van Wee and Börjesson, 2015). Racca and Dhanju (2006) report that properties in the close proximity of bike paths are sold at 4% higher prices than similar homes without bike paths.

Transportation infrastructure that is designed with a focus on motorized transport, with expanded roadways designed for fast speeds and with high parking requirements, leads to the contribution of **urban sprawl**. In contrast, areas that are developed with a focus on walking and cycling lead to a more sustainable form of land use, which Litman (2022) calls "**Smart Growth**". Not only are active transport modes more compact in terms of space occupation, they also enhance the public realm by creating spaces where people naturally interact. Differently put, an area focused on walking and cycling is a more liveable neighbourhood.

Moreover, Smart Growth triggers **positive spill-over effects**, further enhancing the benefits of cycling. For example, the development of a safe biking path in the proximity of a school leads to more children being active, reduced car traffic (and therefore lower congestion), less accidents, and indirect benefits due a smaller amount of land that must be paved for car parking facilities. In general, people who live in cycle-friendly areas own fewer cars and drive less. This means that they face lower private transportation costs and in addition they avoid external costs such as traffic congestion, accident risk and pollution. Litman (2009) calculates that the spill-over effects from regular cycling in cycling-friendly areas can provide thousands of dollars per capital per year in savings and benefits.

To conclude the **increased (urban) quality** that results from cycling should be taken into account in a cost-benefit analysis of cycling versus alternative transport modes. Several studies indicate that this benefit may be very large, if not **the most important societal benefit caused by cycling**. However, urban quality is very difficult to monetise. Therefore, most studies only discuss this benefit qualitatively.

Litman (2022) calculates the benefits of cycling with respect to the reduced pavement requirement and the reduction of urban sprawl (increased accessibility) for the United States. This is the only study that provides general cost estimates to value the effect of improved urban quality. Because of the lack of regional-specific numbers, we use the values for the U.S. in this study. However, we stress that when a cost-benefit analysis is made for a specific cycling infrastructure project, a location-specific valuation should be performed.

Table 3.20 Benefits from improved quality of the environment (€/pkm)

	Urban peak	Urban off-peak	Rural	Total
Reduced pavement	€ 0.01	€ 0.003	€ 0.001	€ 0.001
Increased accesibility	€ 0.05	€ 0.04	€ 0.019	€ 0.032
Total	**€ 0.06**	**€ 0.04**	**€ 0.019**	**€ 0.033**

Source: Litman (2022), converted to euro at a 1 dollar for a euro exchange rate

We use the values shown in Table 3.20 for push bikes. We determine the benefits of an improvement in living areas from e-biking and speed pedelecs by rescaling the values in the table by the difference in average annual mileages. That is, the benefits from e-bikes and speed pedelecs are respectively equal to € 0.02/pkm and € 0.01/pkm.

Summary – Space occupation

Bicycles are more **space-efficient** than cars. A single car parking spot can park up to 15 bicycles, and the same amount of road space can be crossed by 7 times more bikes than cars.

Areas focused on cycling are **more liveable environments and reduce urban sprawl**.

3.11 Infrastructure costs

Infrastructure costs for passenger transport are highly dependent on the transport mode and type of infrastructure (regular road versus bridge or tunnel). In the cost-benefit analysis we use average infrastructure costs, allocated to each transport mode based on the number of person kilometres or the on the number of citizens.

Infrastructure costs comprise the following items:
- construction costs,
- renewal costs,
- maintenance costs,
- operational & management costs.

There is a difference between average infrastructure costs and marginal infrastructure costs. Average infrastructure costs are calculated by allocating the total infrastructure costs over the different transport modes. Average infrastructure costs are relevant when we want to calculate the impact of new infrastructure.

Marginal infrastructure costs are the costs for one additional transport user. These comprise mainly the maintenance and repair costs caused by a user of the infrastructure. Marginal infrastructure costs are relevant when we calculate the costs and benefits of a modal shift or a change in the traffic volumes, without a change in infrastructure.

Schroten et al (2014) report the average and marginal infrastructure costs per transport mode for the Netherlands. The authors provide detailed data and make a distinction between costs for urban and rural areas. The figures in Schroten et al. (2014) are for 2010 and are somewhat outdated. In addition, they are only available for the Netherlands.

In EC DG MOVE (2019), infrastructure costs are calculated for all EU countries and are updated to 2016. A downside of this publication is that it doesn't include cycling infrastructure costs and that there's no distinction between urban and rural areas. We can estimate the costs of cycling infrastructure by assuming that the ratio of cycling infrastructure costs versus costs for passenger car infrastructure is constant over time. More specifically, based on Schroten et al (2014), cycling infrastructure costs are 30% of infrastructure costs allocated to passenger cars. Hence, we can use the ratio from Schroten et al (2014) to estimate cycling infrastructure costs per country.

Table 3.21 and Table 3.22 show respectively the average and marginal infrastructure costs allocated to each transport mode for the four countries in this study.

Table 3.21 Average infrastructure costs in €/1000 pkm (€_2022 prices)

	BE	DE	LU	NL
Passenger car	€ 21.77	€ 21.28	€ 18.57	€ 37.94
Bus	€ 39.19	€ 42.11	€ 29.75	€ 97.54
Train	€ 192.16	€ 110.46	€ 1 357.96	€ 195.83
Bike	€ 6.53	€ 6.38	€ 5.57	€ 11.38

Source: EC DG MOVE (2019) and Schroten et al. (2014)

Table 3.22 Marginal infrastructure costs in €/1000 pkm (€_2022 prices)

	BE	DE	LU	NL
Passenger car	€ 1.39	€ 1.26	€ 1.23	€ 3.99
Bus	€ 19.20	€ 19.52	€ 13.56	€ 48.96
Train	€ 30.61	€ 16.58	€ 153.29	€ 24.23
Bike	€ 0.42	€ 0.38	€ 0.37	€ 1.20

Source: EC DG MOVE (2019) and Schroten et al. (2014)

Summary

Bicycle infrastructure is several times cheaper to develop and maintain than other types of passenger transport infrastructure.

4 CBA of cycling: results and modal shift impact

In this chapter, we synthesise the results of the cost-benefit analysis that was described in Chapter 3. For each country and region, we respectively discuss the private, external and social costs and benefits of the different passenger transport modes (push bikes, e-bikes, speed pedelecs, passenger cars, bus and train). Next, we demonstrate the impact of a potential modal shift from passenger cars to cycling and from using public transportation to cycling. Finally, we provide a brief discussion on the difference between urban and rural areas.

KEY TAKEAWAYS

Each kilometre cycled provides a benefit to society.

In the Benelux-NRW, the social benefits per kilometre cycled are equal to 98 eurocents for a push bike and 22 eurocents for an e-bike. Riding a speed pedelec creates a social cost of 25 eurocents per kilometre, but these are mainly private costs for the user. The external effects of riding a speed pedelec are positive. A trip by passenger car creates a social cost of € 1.02 per kilometre.

Per year, each cyclist creates a social benefit ranging between € 260 and € 694. A car user creates a social cost of € 15 227 per year.

The social benefits of cycling sprout mainly from important positive health effects. Therefore, **in investment in cycling infrastructure is an investment in public health**.

A modal shift from passenger cars to cycling yields significant social gains. If 1% of all car passenger-kilometres in the Benelux-NRW region would be replaced by bicycle trips, **a net social benefit of € 13.4 billion per year** could be realised.

Each five-kilometre trip by car that is replaced by a push bike yields € 10 to society. An eight-kilometre car ride replaced by an e-bike generates € 9.8 in social gains. Every speed pedelec that rides twenty kilometres previously covered by car creates a net social benefit of € 15.2.

100 000 people that commute by push bike on a 5-km one-way trip instead of using a car,
100 000 people that commute by e-bike on a 8-km one-way trip instead of using a car,
100 000 people that commute by speed pedelec instead of by car on a 20-km one-way trip,
generate a total social benefit of 1.4 billion euro per year for the Benelux-NRW region.

4.1 CBA of cycling in the Benelux-NRW

We calculate the social costs and benefits of all passenger transport modes considered in this study for the Benelux and NRW. Figure 4-1 shows the results. The total social costs (if negative) and benefits (if positive) are represented by the black line. The stacked bars show the main components of the social costs.

The figure demonstrates that riding a bicycle leads to significant social gains. Each kilometre covered by a push bike generates 98 eurocents in social benefits, while e-biking yields a social gain of 22 eurocents per kilometre. All other modes of passenger transport lead to a social costs. Riding a speed pedelec generates the lowest social cost, notably 25 eurocents per kilometre. The majority of these costs are private costs borne by the user. For the rest of society, a speed pedelec creates a positive external effect. The highest social cost is caused by a passenger car. Each passenger kilometre in a passenger car creates a social cost of € 1.02.

The positive effect of cycling is caused by the health impact of cycling. Cycling results in important health effects that benefit both the cyclist and the rest of society. Regular cycling leads to lower mortality and morbidity risk and social security savings resulting from improved fitness and health. Yet, the most important health effect from cycling is the higher level of productivity. Regular cycling leads to less sick days. With the high economic value of labour productivity in the Benelux-NRW region, the productivity gains from cycling translate into a significant economic benefit.

Combining the CBA-results in Figure 4-1 with the average yearly mileage of each transport mode, implies that every cyclist generates a yearly social benefit ranging from € 260 (e-bike) to € 694 (push bike). A passenger car that covers 15 000 km per year leads to an annual social cost of € 15 227.

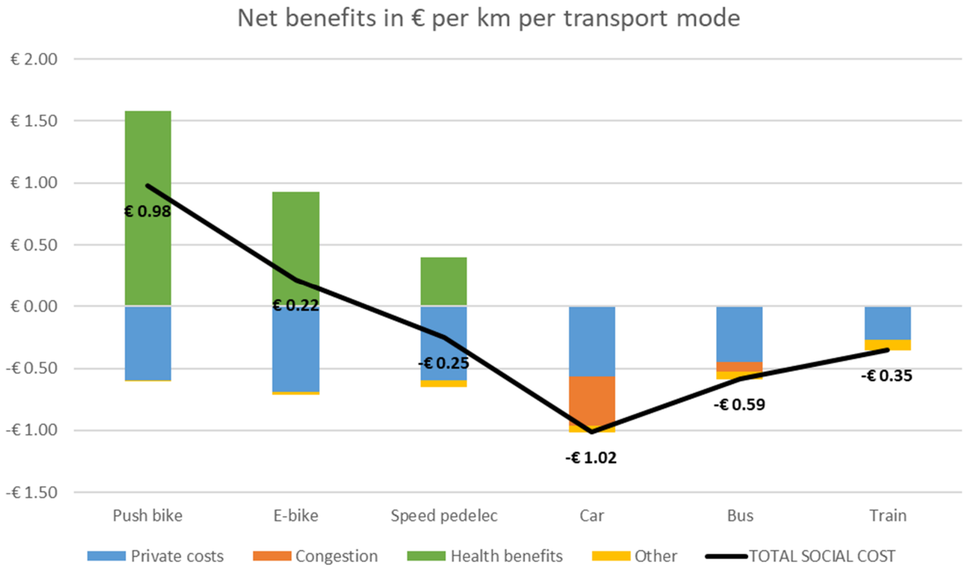


Figure 4-1 Social costs and benefits of different passenger transport modes in the Benelux and NRW

The high social costs of passenger car use sprout predominantly from two factors: (1) high private costs, and (2) high congestion costs.

The results of the cost-benefit analysis imply that the economic value of a modal shift from passenger cars to bicycles is enormous. **If only 1% of all passenger-kilometres covered by car in the Benelux-NRW would be replaced by bicycle rides, a total social benefit of € 13.4 billion can be realized.**[29]

Figure 4-2 shows the economic benefits from a modal shift to biking per passenger transport mode and per bike type. The benefits are expressed in euro per kilometres, which might give the false impression that push bikes lead to the highest gains. However, we should take into account that the distance covered on pedal-assisted bicycles is significantly longer than on a push bike.

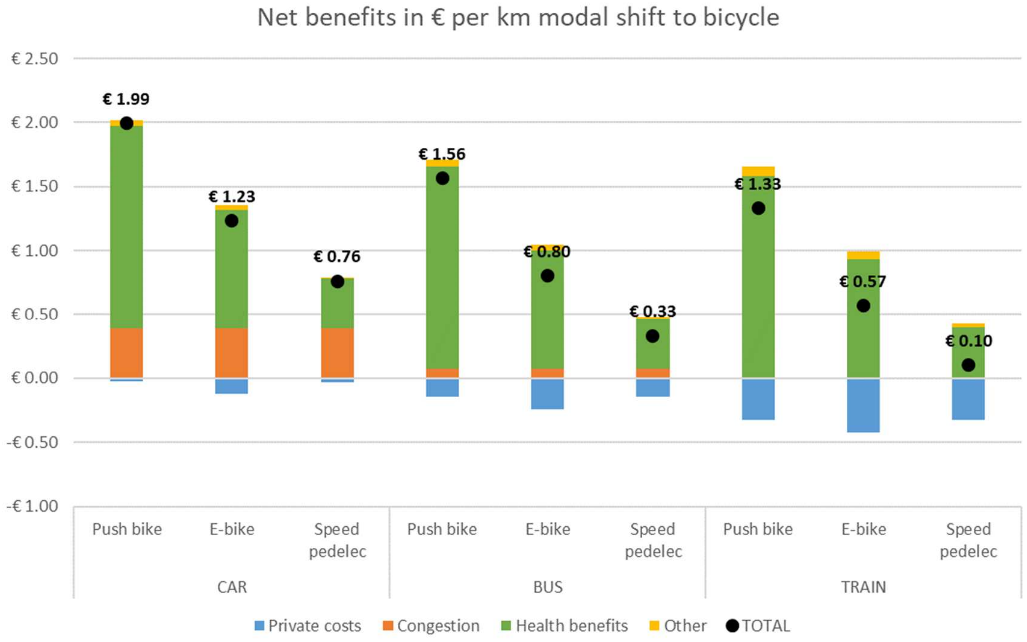


Figure 4-2 Social benefit from a modal shift to cycling in the Benelux-NRW

Riding a push bike instead of sitting in a passenger car for a 5-km trip, results in a social gain of 10 euro. A 8-km long e-bike ride that replaces a car ride yields € 9.8 in social gains. Every passenger car trip of 20 km that is exchanged for a ride on a speed pedelec results in social benefits with an economic value of € 15.2.

To assess the full potential of a modal shift, we look at the average distance of car trips. For Belgium, the Monitor (2019) study reports that 12% of all trips by passenger car are shorter than one kilometre. 44% of all passenger car trips have a length up to 5 kilometres, and 79% of all trips are shorter than 20 km. This means that the potential for a modal shift towards cycling is very large.

The challenge is to raise public awareness about these potential social benefits and to equip policy makers with the correct tools to make such a large-scale modal shift possible. In Chapter 6 we discuss the policy recommendations that sprout from our study.

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[29] Assuming a bicycle mix composed of 40% push bikes, 40% e-bikes and 20% speed pedelecs.

4.2 CBA of cycling in Belgium

4.2.1 Private costs and benefits

The private costs per person kilometre (pkm) for different transport modes in Belgium is shown in Figure 4-3. The figure shows the different components of the private costs in the bars. The total private costs are shown by the blue line. Private costs range from € 0.70/pkm for an e-bike to € 0.33/pkm for train.

In Belgium, a bicycle is the most costly mode of passenger transportation in terms of private costs. Although the total costs of ownership for a bicycle are lower than those of a passenger car, this lower cost of ownership is compensated by a higher time cost. Because a bicycle trip, on average, takes more time than a comparable trip by car or public transportation, people face relatively high time costs. Hence, in order to stimulate cycling in Belgium, cycling paths should be designed that allow for a faster and safer passage of cyclists.

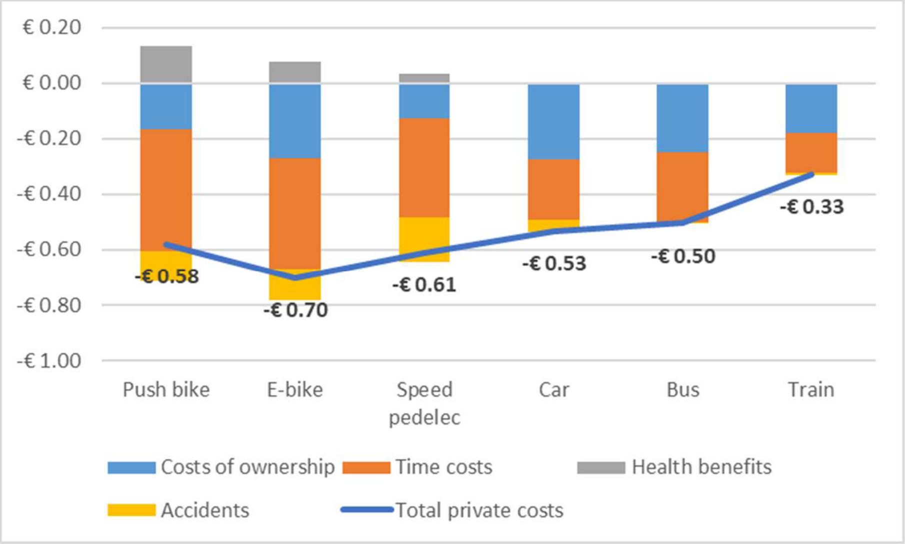

Figure 4-3 Private costs per passenger transport mode in Belgium (€/pkm)

4.2.2 External costs and benefits

The external costs and benefits show in the figure below demonstrate that all form of cycling lead to large external benefits. These benefits are predominantly health effects, and to a lesser extent resulting for improved living environments. In terms of euro per kilometre, the external benefits of push bikes are the largest (€ 1.48/pkm). However, in absolute terms, the external benefits are similar across bicycle types because e-bikes and speed pedelecs ride more kilometres than push bikes.

The other modes of passenger transport lead to external costs to society. For public transportation, the external costs are relative low. Transport by bus creates a social cost of € 0.12/pkm and transport by train costs € 0.05/pkm. Using a passenger car leads to the largest external cost, notably € 0.42/pkm. The main driver of this cost are congestion costs.

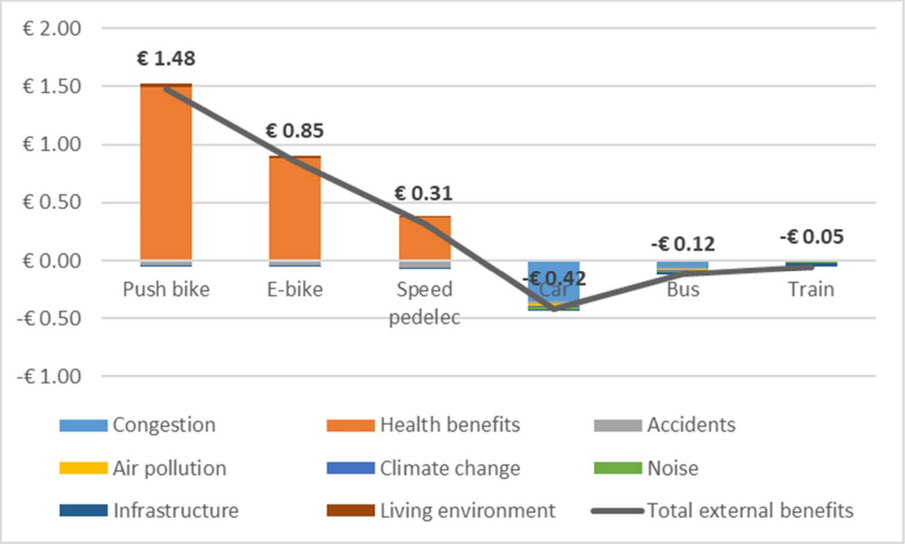

Figure 4-4 External costs (-) and benefits (+) per passenger transport mode in Belgium (€/pkm)

4.2.3 *Social costs and benefits*

The social costs and benefits of the different transport modes are shown in Figure 4-5. Private costs are represented by blue bars, while external effects are shown in green. The total social costs and benefits are plotted with a black line.

It is clear from the figure that push bikes and e-bikes result in net benefits for society. Basically, this means that with every kilometre cycled, society gains. For speed pedelecs, we find a net cost. The health benefits for riding a speed pedelec are insufficient to compensate for the private costs.

The most costly form of passenger transport is a passenger car. Every person kilometre driven by a passenger car leads to a net cost to society of 96 eurocents. Using public transportation leads to lower social costs, notably € 0.63/pkm for transport by bus and € 0.38/pkm for a passenger train.

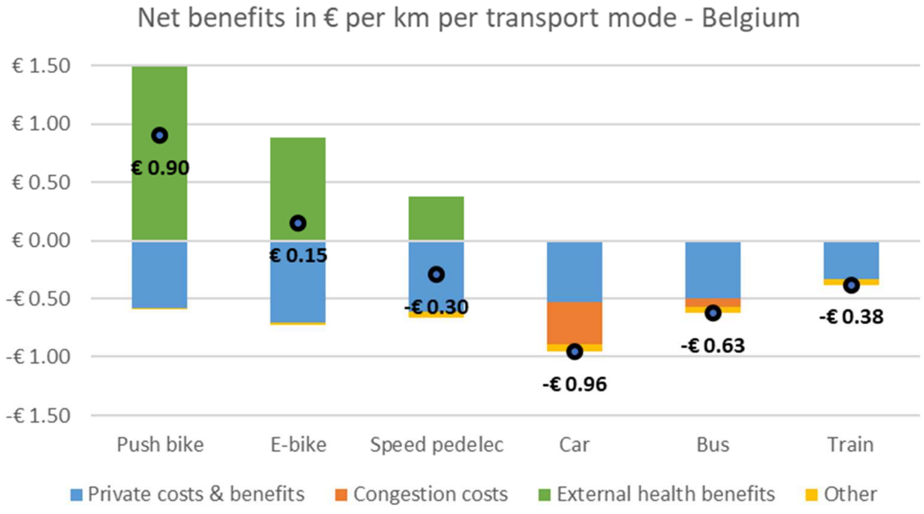

Figure 4-5 Social costs (-) and benefits (+) per passenger transport mode in Belgium (€/pkm)

4.2.4 Modal shift from passenger cars or public transport to cycling

The main interest of this study is to understand the impact of a modal shift towards cycling. **Our results show that the exchange of a trip by passenger car to a bicycle ride leads to significant benefits to society.** This finding is true for any type of bicycle. In euro per kilometres terms, the gain is the largest for a push bike. A modal shift from a passenger car to a push bike leads to a societal benefit of € 1.86 per person kilometre. Exchanging your car for an e-bike or speed pedelec leads respectively to a gain of € 1.11/pkm and € 0.66/km.

A modal shift from public transportation leads to comparable, although lower social benefits. The benefits from a modal shift from a bus ride to a bike ride range between € 0.33/pkm to € 1.53/pkm and the net social gains from a modal shift from train to bike range between € 0.09/pkm and € 1.28/pkm. Note that a modal shift from train rides to cycling may be less realistic. Train rides are typically used for longer distance trips, which are less easily replaced by a bicycle ride.

To put the numbers in Figure 4-6 into perspective, we calculate the total social gains that can be realized with a modal shift from cars to bicycles. According to the Federal Planning Bureau, 142.79 billion person kilometres were covered by passenger car in Belgium in 2019 (Daubresse et al., 2022). **If one percent of these pkm would be replaced by push bike rides, this would lead to a total social benefit equal to € 2 653 million. Replacing one percent of the car pkm by speed pedelec would result in a net social gain of € 946 million.**

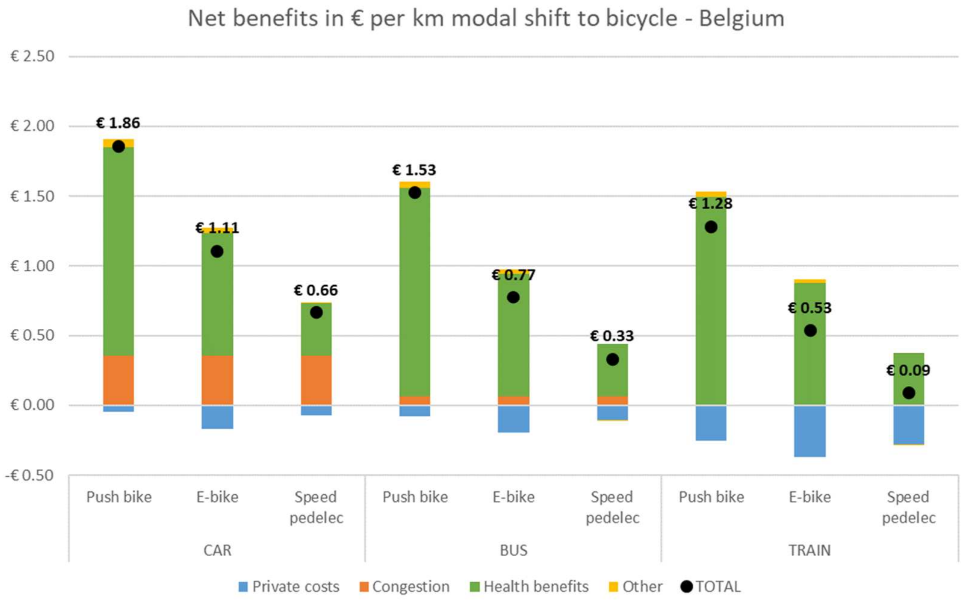

Figure 4-6 Economic impact of a modal shift towards cycling in Belgium (€/pkm)

Consider the following hypothetical scenario:

- 100 000 people commute by push bike instead of using a passenger over a one-way distance of 5 kilometres during 200 working days per year,
- 100 000 people exchange their passenger car commuting trip for an e-bike ride of a one-way distance of 8 kilometres,
- 100 000 people commute to work by speed pedelec instead of by car over a distance of 20 kilometres.

This scenario would lead to **a total social benefit of 1.3 billion euro per year**. This social benefit consists mainly of health benefits (€ 880 million per year) and the avoidance of congestion costs (€ 471 million per year).

4.3 CBA of cycling in Luxembourg

4.3.1 Private costs and benefits

In Luxembourg, time costs are relatively high because of the high share of commuting trips in the total share of trips. Because time spent while commuting is valued much higher than time spent on leisure trips, a slower speed results in significant private costs. The private costs for riding a bicycle vary from €0.69/pkm on a speed pedelec to €0.78/pkm on an e-bike. In comparison, a ride with a passenger car, costs only € 0.59/pkm. Using public transportation in Luxembourg is very cheap. Because public transportation is free of charge, the user only incurs time costs. In addition, accident risk for public transport is very low.

Another reason for this relatively large difference in private costs between passenger cars and bicycles is the commuting allowances that exists for passenger cars but is not awarded to commuting by bicycle. This lowers the running costs of cars.

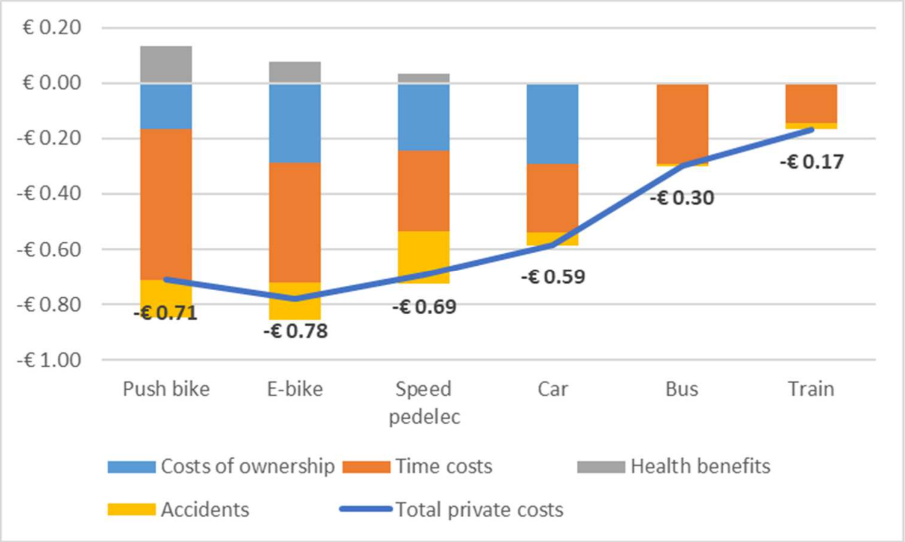

Figure 4-7 Private costs per passenger transport mode in Luxembourg (€/pkm)

4.3.2 External costs and benefits

The external effects of each transport mode are shown in Figure 4-8. Riding a bicycle leads to significant external benefits. The main source of these benefits are positive health effects. Cycling leads to a reduced risk of serious diseases and boosts physical fitness. As a result, people who cycle regularly need less sick days and have a higher labour productivity. With labour productivity in Luxembourg being one of the highest in Europe, this positive productivity effect contributes to a large extent to the external benefits of cycling.

In contrast, driving a passenger car causes external costs. The majority of these costs consist of congestion costs. Public transportation comes at a small external cost. The external costs of a train ride (€ 0.21/pkm) are somewhat higher than those of a bus ride (€ 0.15/pkm) because of the higher marginal infrastructure costs for this transport mode.

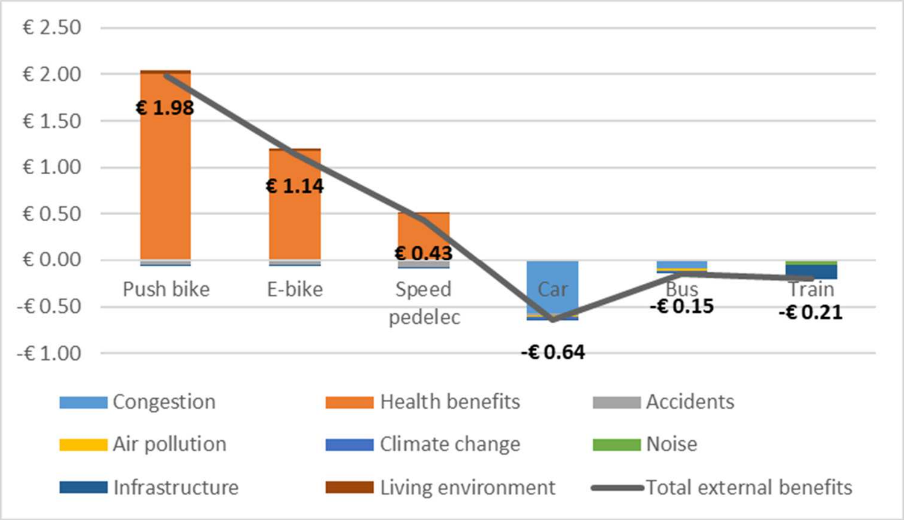

Figure 4-8 External costs (-) and benefits (+) per passenger transport mode in Luxembourg (€/pkm)

4.3.3 Social costs and benefits

The social benefits of cycling in Luxembourg are large. They range from € 1.27/km for a push bike to € 0.36/km for e-bikes. Speed pedelecs lead to a net social cost of € 0.27/km. The source of this social benefit for cycling are the external health benefits that are equal to € 2 per km for push bikes, € 1.2 per km for e-bikes and € 0.50 per km for speed pedelecs. The lower per-km gains for electric bicycles are compensated by the longer distances that are covered by these bike terms. When these higher mileages are taken into account, health benefits are comparable across bicycle types.

The most costly way of passenger transport for society is the passenger car. Per km driven, a passenger car leads to a net social costs of € 1.22. Lower social costs are caused by public transportation, more specifically bus trips cost € 0.45/pkm and train trips cost € 0.37/pkm.

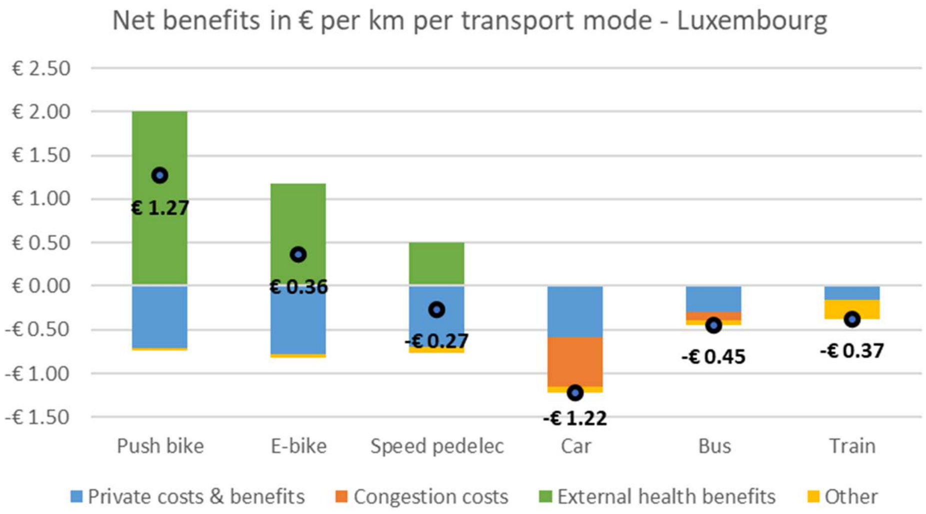

Figure 4-9 Social costs (-) and benefits (+) per passenger transport mode in Luxembourg (€/pkm)

4.3.4 Modal shift from passenger cars or public transport to cycling

If people exchange the car for a bicycle, significant gains can be realized in Luxembourg. In euro per kilometre, these gains are the highest if a push bike is used. Switching from passenger car to a push bike leads to a net social benefit of € 2.49/person-km (Figure 4-10). These net benefits result from the combination of achieving the benefits from cycling (mainly attributable to positive health effects) and avoiding the costs from car use.

The net gains from a modal shift towards e-bikes and speed pedelecs are lower, respectively € 1.59 per person-km and € 0.96 person-km. However, because longer distances are travelled with these bicycle types, the lower per unit benefits are compensated by higher mileages. E-bikes and speed pedelecs have the potential to replace longer car trips than push bikes.

Each five-kilometre trip by passenger car that is replaced by a push bike, yields a social benefit of € 12.45. A twelve-kilometre trip covered by e-bike instead of a car leads to € 19.08 in benefits; and a twenty-kilometres car ride that is exchanged for a ride on a speed pedelec results in a gain for society equal to € 19.2.

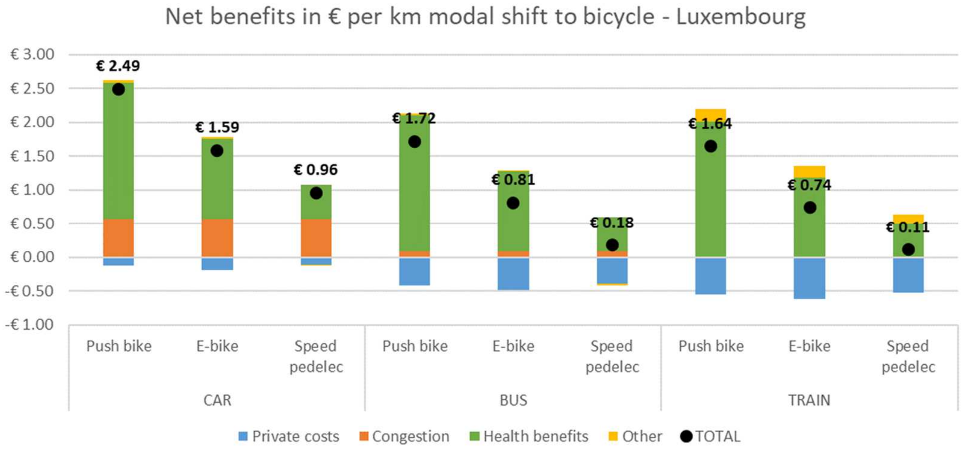

Figure 4-10 Economic impact of a modal shift towards cycling in Luxembourg (€/pkm)

Consider the following hypothetical scenario:

- 100 000 people commute by push bike instead of using a passenger over a one-way distance of 5 kilometres during 200 working days per year,
- 100 000 people exchange their passenger car commuting trip for an e-bike ride of a one-way distance of 8 kilometres,
- 100 000 people commute to work by speed pedelec instead of by car over a distance of 20 kilometres.

This scenario would lead to **a total social benefit of 1.8 billion euro per year**. This social benefit consists mainly of health benefits (€ 1 180 million per year) and the avoidance of congestion costs (€ 753 million per year).

4.4 CBA of cycling in the Netherlands

4.4.1 Private costs and benefits

The Netherlands is the only country in our study where the private cost of riding a bicycle are lower than those of a passenger car. This is the case for push bikes (€ 0.56/pkm) and speed pedelecs (€ 0.57/pkm). The private costs of passenger cars are estimated at € 0.62/pkm. This difference in private costs is one of the reasons why cycling in the Netherlands is more prevalent than elsewhere in Europe. However, it also is a reflection of a different culture and attitude towards cycling versus passenger transport by car. Public policy and road infrastructure in the Netherlands is designed in a way that stimulates bicycle use. In addition, relatively high taxes for motorized transportation lead to high costs of ownership of (fossil fuel) cars.

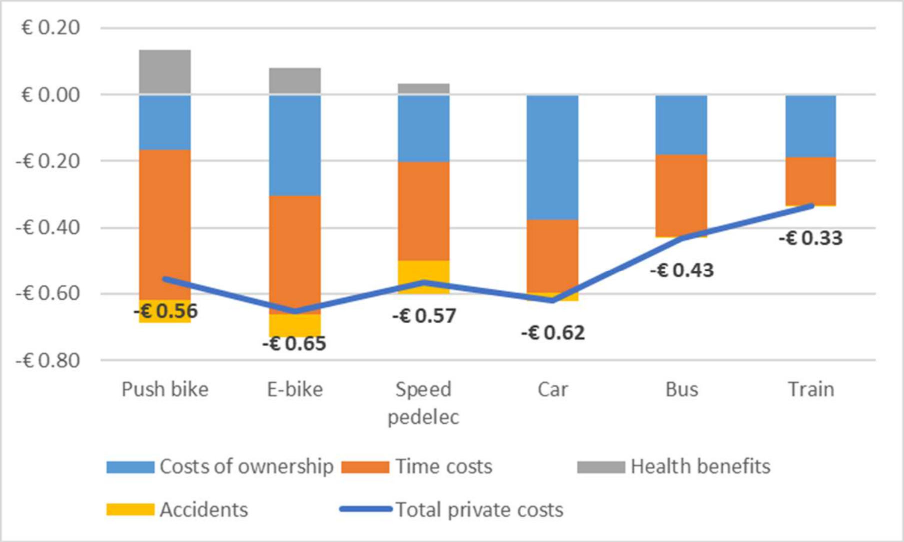

Figure 4-11 Private costs per passenger transport mode in the Netherlands (€/pkm)

4.4.2 External costs and benefits

Riding a bicycle leads to positive external effects, irrespective of the bicycle type. In per-kilometre terms, the gains are the largest for push bikes that generate an external benefit of € 1.45/km. E-bikes and speed pedelec rides result in lower per unit gains, but these are compensated by the higher distances ridden on these bicycles.

Other modes of passenger transport create an external cost. The costs to society are the largest for passenger cars, € 0.42/km. Congestion costs are the main contributor to these external costs. A train ride causes very low external costs because congestion effects are less of an issue on the rail network. Passenger transport by bus leads to an external cost of € 0.17/km.

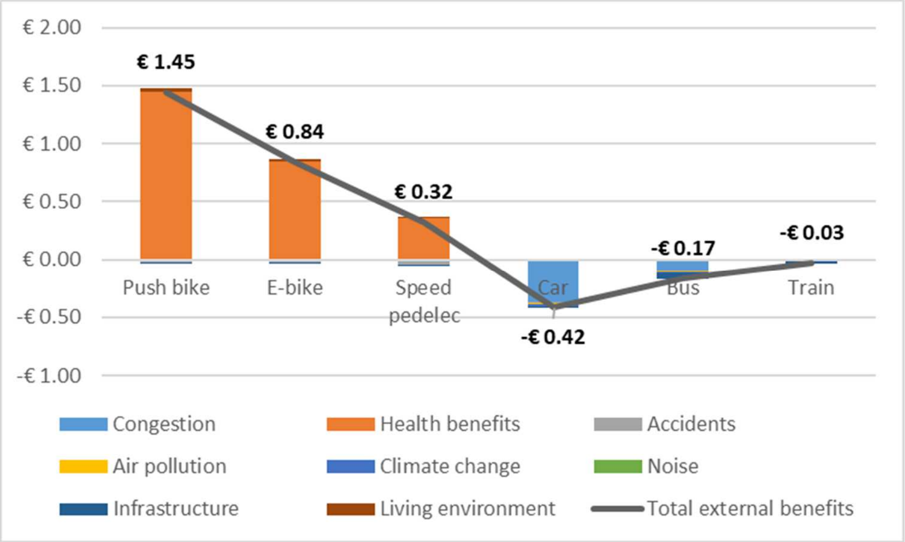

Figure 4-12 External costs (-) and benefits (+) per passenger transport mode in the Netherlands (€/pkm)

4.4.3 Social costs and benefits

The numbers in Figure 4-13 show that society benefits from every kilometre cycled. A ride on a push bike yields a social benefit of € 0.89 per km, while each e-bike ride results in a € 0.18 per km benefit. Because the per-kilometre benefits are smaller for a speed pedelec, these bike types generate a social cost of € 0.24 per km. However, these costs are carried by the user of the speed pedelec, not by society. The external effects shown in Figure 4-12 demonstrate that a trip by speed pedelec results in positive effects to society.

The use of a passenger car is relatively costly in the Netherlands. A person-kilometre driven by car leads to a social cost of € 1.04. Public transportation comes at a cost of € 0.60 per person-km for bus trips and € 0.37 per person-km for car trips.

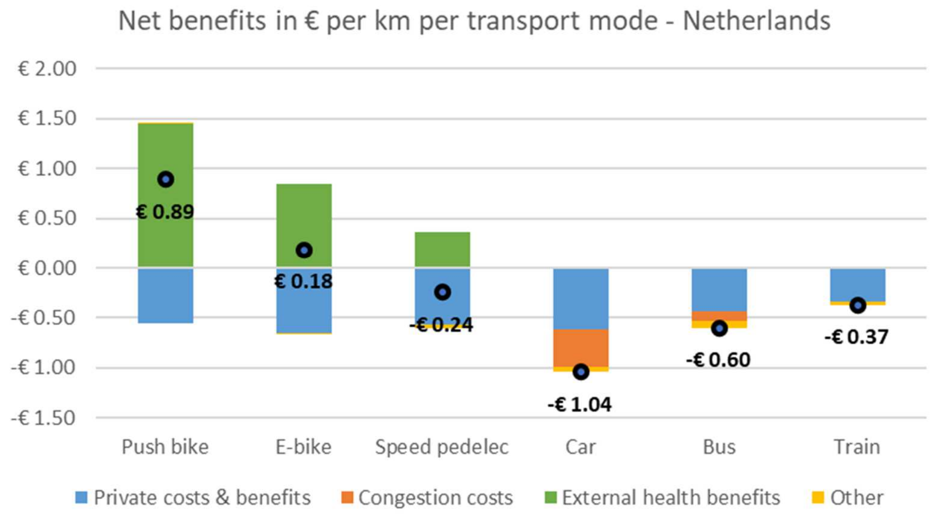

Figure 4-13 Social costs (-) and benefits (+) per passenger transport mode in the Netherlands (€/pkm)

4.4.4 Modal shift from passenger cars or public transport to cycling

A modal shift from passenger cars or public transportation to cycling leads to significant social benefits. The net benefits from riding a bicycle are enhanced by the cost savings that are realized by this mode shift. The gains to society are the largest when a passenger car trip is exchanged for a bicycle trip. The net social benefits are equal to € 1.93 per person-km, € 1.22 per person-km and € 0.79 per person-km for respectively a push bike, e-bike and speed pedelec.

The net social gains that are realized by switching for public transportation to cycling are lower, but still significant. They range from € 1.49 per person-km for push bikes to € 0.12 per person-km for speed pedelecs.

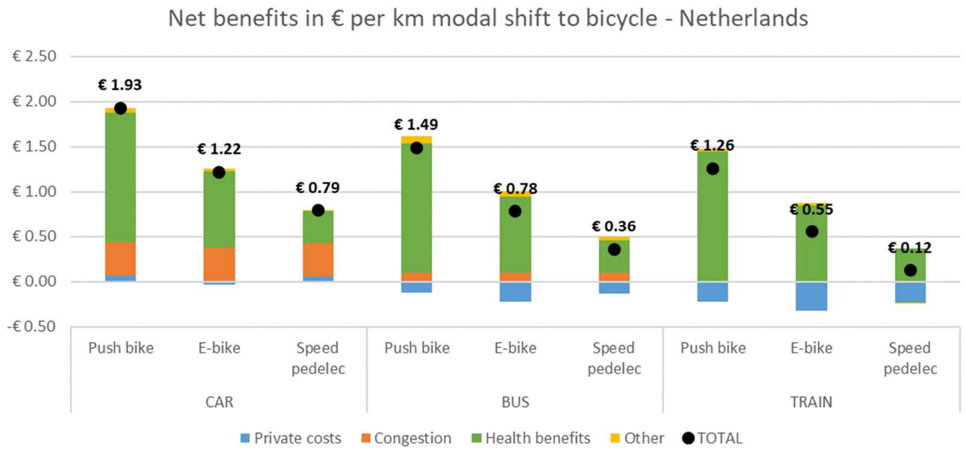

Figure 4-14 Economic impact of a modal shift towards cycling in the Netherlands (€/pkm)

Consider the following hypothetical scenario:

- 100 000 people commute by push bike instead of using a passenger over a one-way distance of 5 kilometres during 200 working days per year,
- 100 000 people exchange their passenger car commuting trip for an e-bike ride of a one-way distance of 8 kilometres,
- 100 000 people commute to work by speed pedelec instead of by car over a distance of 20 kilometres.

This scenario would lead to **a total social benefit of 1.4 billion euro per year**. This social benefit consists mainly of health benefits (€ 850 million per year) and the avoidance of congestion costs (€ 491 million per year).

4.5 CBA of cycling in North Rhine-Westphalia

4.5.1 Private costs and benefits

In North Rhine-Westphalia, the private costs of using a bicycle are comparable to the costs of driving a passenger car or taking the bus. In terms of private costs, a train ride is cheapest as it costs only € 0.25/pkm. However, the cost estimates for bus and train reported in Figure 4-15 are to be interpreted with caution. We used prices for single tickets and made assumptions about the average length of the trips by public transport. For bus rides, we assumed an average trip length of 10 km, for train trips we assumed a trip length of 40 km. Hence, the costs per ride may differ significantly depending on the fare type (subscription, day pass, reduced tariff) and the trip length.

Riding a bicycle costs less than a car or a bus ride if we look at total costs of ownership.[30] However, these lower costs are compensated by the higher time cost for bike riders.

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[30] For buses, these are use costs, not ownership costs.

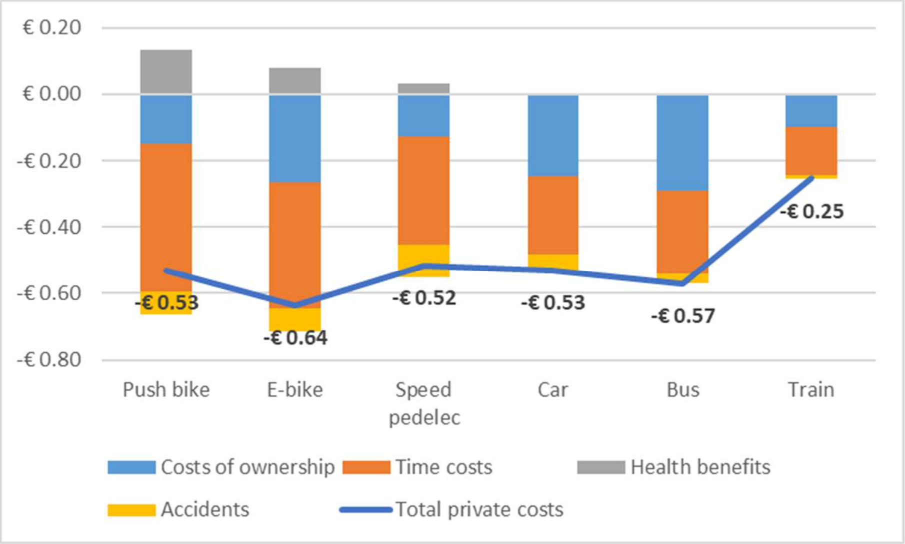

Figure 4-15 Private costs per passenger transport mode in NRW (€/pkm)

4.5.2 *External costs and benefits*

The external effects resulting from the different modes of passenger transport are shown in Figure 4-16. Cycling leads to significant external benefits, irrespective of the bicycle type. Riding a push bike yields € 1.38/km in external benefits, an e-bike ride results in € 0.80/km in external gains and each kilometre covered by a speed pedelec leads to € 0.31 in external benefits. These external benefits are predominantly health benefits and sprout to a lesser extent from an improved quality of the living environment.

In contrast, each kilometre covered by car leads to an external cost of € 0.31. Train and bus rides cause only very small external costs, respectively € 0.04/pkm and € 0.10/pkm.

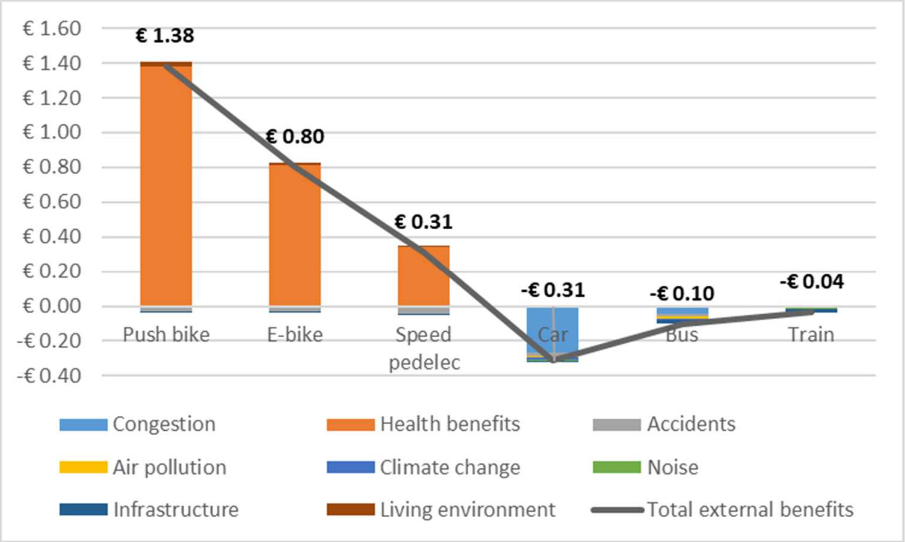

Figure 4-16 External costs (-) and benefits (+) per passenger transport mode in NRW (€/pkm)

4.5.3 Social costs and benefits

Riding a push bike or an e-bike in North Rhine-Westphalia leads to a net social gain of respectively € 0.85/km and € 0.16/km. A ride on a speed pedelec comes with a small social cost of € 0.21/km. However, these are all private costs, which are borne by the user. The external benefits of riding a speed pedelec are positive, meaning that society still benefits from speed pedelec rides.

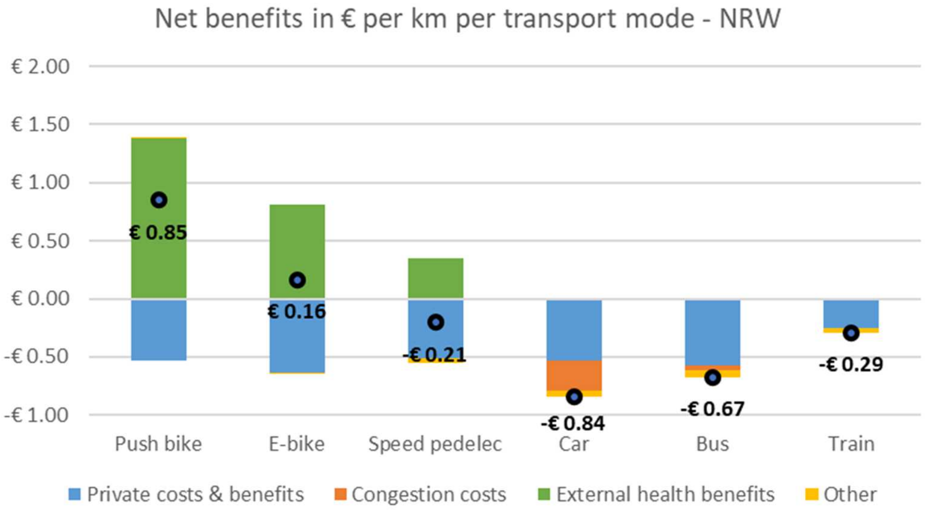

Figure 4-17 Social costs (-) and benefits (+) per passenger transport mode in NRW (€/pkm)

4.5.4 Modal shift from passenger cars or public transport to cycling

Figure 4-18 shows the net benefits from a modal shift towards cycling in NRW. The benefits are expressed in euro per kilometre which explains the lower benefits for high mileage bikes. The numbers in the figure indicate that the potential benefits of a modal shift to cycling are very large. Each kilometre covered by a push bike trip that replaces a car or public transport trip leads to a net social gain in a range of € 1.14 to € 1.69. The economic value of a modal shift to e-bikes are equal to € 0.46 to € 1.01 per person-km, and a modal shift to speed pedelecs yields € 0.08 per person-km to € 0.64 per person-km to society.

To put these numbers in perspective, we consider trips with an average length of respectively, five, eight and twenty kilometres. Each 5-km car trip that is replaced by a push bike yields € 8.45. A 8-km trip that is covered by e-bike leads to a social gain of € 8.08. A 20-km car ride that is exchanged for a ride on a speed pedelec leads to a net benefit of € 12.80.

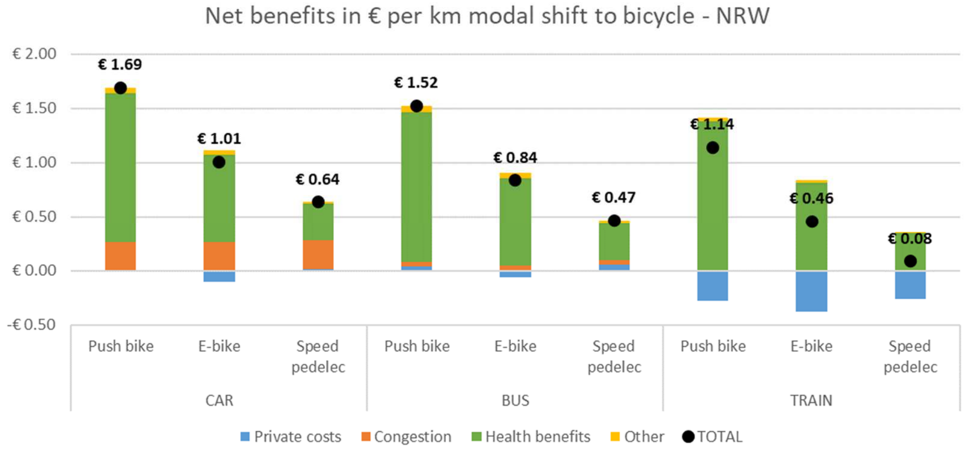

Figure 4-18 Economic impact of a modal shift towards cycling in the NRW (€/pkm)

Consider the following hypothetical scenario:

- 100 000 people commute by push bike instead of using a passenger over a one-way distance of 5 kilometres during 200 working days per year,
- 100 000 people exchange their passenger car commuting trip for an e-bike ride of a one-way distance of 8 kilometres,
- 100 000 people commute to work by speed pedelec instead of by car over a distance of 20 kilometres.

This scenario leads to **a total social benefit of 1.2 billion euro per year**. This social benefit consists mainly of health benefits (€ 810 million per year) and the avoidance of congestion costs (€ 347 million per year).

4.6 Urban versus rural environment

The cost-benefit analysis presented in this study assumed average values with respect to speed, time costs, living conditions, accidents. Several studies have demonstrated that transportation costs differ considerably between urban and non-urban environments. For example, the average speed of a passenger car is significantly lower in a city centre compare to rural areas. In 2021, the average speed by cars in Brussels was only 16 km/h.[31] In urbanized areas, the bicycle is often the fastest transport mode. This is especially true when parking search costs are taken into account (Dutch Cycling Vision, 2018).

Apart from time and congestion costs, other elements of the cost-benefit analysis are also influenced by the environment. Accident risk is typically higher in an urban environment. An exception are bicycle-friendly cities such as Copenhagen and Amsterdam. Cycling cities have much higher levels of traffic safety and record fewer casualties among cyclists (Dutch Cycling Vision, 2018).

The positive impact of cycling infrastructure and cycling areas on the living environment is higher in urban areas than in rural areas.

All these arguments imply that the benefits from cycling and the external costs of passenger cars are enhanced in an urban environment. Therefore, the economic value of a modal shift towards cycling is the highest in cities and suburban areas.

Every person that cycles to work instead of taking the car for a 7 km (one-way) commuting trip in an urban area saves € 1 251 per year in congestion costs only. In rural areas the congestion cost savings are equal to € 936 per person per year.

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[31] https://inrix.com/scorecard-city/?city=Brussels&index=3

5 Case study: cross border cycle highway Arlon-Luxembourg

KEY TAKEAWAYS

The realisation of an Arlon-Luxembourg cycle highway through a significant upgrade of existing infrastructure provides at least 80% more benefits than costs.

Arlon-Luxembourg proved to have the highest cross-border potential in the Benelux -Nord Rhein Westphalen region.

We investigate two cycle highway alternatives: upgrading existing infrastructure (alt 2) or building a new cycle highway (alt 4)

Improving the existing infrastructure provides at least 80% more benefits than costs. In a more probably scenario, benefits are nearly 9 times larger than the costs. Only in a scenario that doubles costs and where few cyclists are attributed to the cycle highway, costs get slightly (10%) bigger than benefits.

Building new infrastructure generates lower benefit over cost ratio's and the net social value becomes negative with pessimistic assumptions. However in a probable scenario, gains are still 30% larger than costs.

In this section we analyse the case of a cross border cycle highway between Arlon (Belgium) and Luxembourg city (Luxembourg). We first show why we choose that cross border connection among many other potential cross border connections in the Benelux-NRW region. Then we propose two concrete alternative routes for the connection and analyse the cost of building and the benefits of using the cycle highway. Due to the limited resources available in this project, the analysis is simplified. To interpret the results correctly, it is **important to read the preliminary remark below.**

Preliminary Remark

In order to make the case study of the Arlon-Luxembourg cycle highway as tangible as possible we provide alternative trajectories. Making the project more tangible is however the only aim. Within this project, we cannot make a detailed analysis of the trajectories, their costs and potential. At this stage, the calculations would however not have been different if another alternative route would have been chosen. Therefore more detailed calculations are necessary. The fact that the trajectories are provided by people how use them for their daily commute means however that it concerns valuable alternatives.

5.1 Why choosing a cross border cycle highway between Arlon and Luxembourg?

5.1.1 *The methodology to choose the most promising cross border cycle highway in the Benelux-NRW area*

In an ideal world, the methodology to choose the most promising cross border cycle highway would consist of comparing the potential for cycling between cities at both sides of a border in the Benelux NRW area. If a Benelux-NRW traffic model would exist, estimating the potential for a cycle highway would be relatively easy by using the model.

However, an integrated Benelux-NRW traffic model does not exist and detailed estimates of transport volumes for cross border origin destination pairs are not publicly available for the area we area we look at.

We therefore use a simple approach based on the available information to estimate the potential of a number of cross border connections.

We used following information:

- Inhabitants of cities. This is a basic indicator for travel potential and journeys generated. The more people living in a city, the higher the number of journeys travelled will be, other factors remaining equal.
- Grensdata database[32]. This database contains numbers of cross border commuters for Belgium, The Netherlands and NRW. This database provides for the Dutch and Belgian cities the number of people working in The Netherlands, Germany or Belgium. For the Belgian and Dutch cities and towns, we know thus how many people cross the border, but we do not know to what city or town they go. For Germany data on people working in Belgium or The Netherlands are not available at the city or town level, but only at a more aggregate level.
- For the Arlon Luxembourg connection we used other data sources, most from studies from the Belgian Luxembourg province as detailed in the next section.
- These data sources were completed with interviews for suggestions for cycle highways among Benelux cycling experts.

All the gathered information is compiled in the table in the section below.

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[32] https://opendata.grensdata.eu/#/InterReg/nl/

5.1.2 The result: an overview of the estimated potential for different cross border connections

The overview table

city (1)	inhabitants (2)	city (3)	inhabitants (4)	distance (5)	language barrier (6)	cycling highway (CH)or other infrastructure (7)	from grensdata.eu; people from city x working in country y					crude estimate of total cross border trips/ workingday (13)
							city (8)	total workers	to B (10)	to Nl (11)	to D (12)	
Arlon	30 000	**Luxemburg**	150 000	30	no	no CH L; cycle paths 12 and 13 L;Cycle path along national route under construction	based on different sources and own hypothesis, gross potential of 7000 workers from Arlon, (could add 1900 from Messancy)					14 000
Genk	70 000	**Maastricht**	122 000	30	no	CH nearly built: F72 Hasselt-Lanaken (Maastricht), link with Genk via F76 (Genk-Tongeren), link with Genk and Maastricht needs work	Maastricht	73510	3560	67790	880	8260
							Lanaken	5840	5520	200	10	
							Hasselt	51590	51290	150	10	
							Genk	35070	34690	220	30	
Venlo	70 000	**Krefeld**	227 000	30	yes	CH feasibility study Venlo-Krefeld done in G,	Venlo	65260	340	57280	**3910**	7820
Venlo	70 000	**Mönchengladbach**	260 000	30	yes	no CH Venlo-Mönchengladbach CH Roermond-Germany planned cycle highway in N	Venlo	65260	340	57280	**3910**	7820
							Mönchengladbach			??		
Heerlen	86 000	**Aachen**	250 000 (Stadtregion)	20-25	yes	CH nearly built; RS4 Aachen-Herzogenrath in G, Kerkrade-Landgraaf in realisatie (Nl)	Aachen			2317		6914
							Heerlen	51380	1070	49150	950	
Landgraaf	37 000			10-15			Landgraaf	10460	140	10110	190	
Gent	265 000	**Terneuzen**	55 000	30-40	no	CH nearly available; B F40 cycle highway Gent-Zelzate +- ready. Nl Terneuzen Sas van Gent planned	Gent	171 450	168960	1250	30	5060
							Zelzate	3430	3220	170		
							Terneuzen	28720	1110	26730	30	
Hengelo	80 000	**Gronau**	46 000		yes	CH avaialble; F35 existing/built	Gronau			422		4220
Enschede	150 000			12			Enschede	79880	70	77770	1590	
							Hengelo	43310	50	42330	520	
Maastricht	122 000	**Aachen**	250 000	30	yes	CH part of ambitions in Nl; LF6 existing	Maastricht	73510	3560	67790	880	4160
							Aachen			1200??		

Table 5.1: overview of the most promising cross border cycle highways

The table shows an overview of the collected data for the most promising potential cycle highways. The table contains following information from left to right:

- City pairs (column 1 and 3)
- Inhabitants in each of the cities of the city pair (column 2 and 4)
- Distance between the city pairs (column 5)
- Presence of a language barrier (column 6)
- What kind of infrastructure is already present (column 7)
- Estimate of number of people commuting from one city (column 8) of the city pair to the other "country", B (Belgium – column 10)), Nl, (the Netherlands -column 11) and D (Germany-column 12)). Figures from German cities to B or Nl were not available in the Grensdata database and have been very crudely estimated.. Remark that the number does not provide a number of people travelling to the other city, but to the other "country". It is therefore overestimating heavily the real potential.

  The Arlon-Luxembourg potential was not estimated using the grensdata base but based on other data. The calculation is explained below.

  - Arlon counts 30 000 inhabitants. 41% of those are active based on the general figure for the province of Luxembourg (Idelux, 2021). 60% of those work in Luxemburg based on a Idelux study from 2016 mentioned in L'essentiel, Luxembourg newspaper (L'essentiel, 19-12-2017). These are 7380 people. The number could be higher as also people from Messancy; a town close to Arlon could use the cycle highway. Following the same calculation method, 1900 people from Messancy could do so! The number could still be higher as the number of cross border workers is systematically increasing, an increase of 14% between 2014 and 2019 (REAL, 2021). The table counts only with the more conservative 7000 people. A more optimistic scenario could therefore count with a potential of 10 000 cross border workers in Belgium.

- The last column provides an estimate of cross border trips assuming that one person doing a cross border commute does two trips per commuting day, one trip go and one return (column 13).

The colour codes in the table indicate to what extent the data is favourable (green) or unfavoirable (dark orange) or in between (salmon)

For the Arlon – Luxembourg example, the table reads as follow: Arlon counts 30 000 inhabitants, Luxembourg 150 000. The distance between both cities is approximately 30 km. There is no language barrier between both cities as both are able to speak French. There is some cycle infrastructure, cycle path 12 and 13 between Luxembourg city and Steinfort, near the Belgian border. The estimated number of commuters is 7000 and maybe even more. This means a potential of 14 000 daily commuter cross border trips.

The distance between Arlon and Luxembourg is at the higher end (salmon), there is some existing infrastructure, but no plans for a cycle highway (green) and the potential is high compared to the other potential cross border links (green).

The 5 links with the highest potential

Based on the table, the most promising links for a cross border cycle highway seem to be

- Arlon -Luxembourg
- Gent-Terneuzen
- Venlo-Mönchengladbach/Krefeld
- Maastricht-Genk/Hasselt
- Heerlen/Landgraaf Aachen

In a previous phase, we have also investigated the potential of following links: Eupen-Aachen, Luik -Aachen, Luik-Maastricht, Turnhout-Tilburg, Lommel-Eindhoven, Bergen-op-Zoom – Antwerpen, Weert-Lommel. The potential of these connections was however low compared to the connections in the table.

The selection of the Arlon Luxembourg cycle highway: highest potential and favorable for intermodality

For all the 5 above mentioned connections with the highest potential, the feasibility of a cycle highway has been studied, a cycle highway is planned, is being realised or exists already. The Arlon-Luxembourg corridor is the exception. No plans exist, nor have studies been done to build a cycle highway. The Arlon-Luxembourg corridor shows furthermore the highest cross border potential.

There are also other reasons to confirm the choice for the Arlon-Luxembourg corridor for a cross border cycle highway. We summarize the different reasons below:

- The **cross border potential** is high, the highest among the studied alternatives. Even if not all the people from Arlon going to the country of Luxembourg do work in the city of Luxembourg, the share of people going from Arlon to the city of Luxembourg among the people going to the country of Luxembourg is most probably larger than the share of people going for example from Venlo to Krefeld among the people going from Venlo to Germany.

- **The inner Luxembourg potential** is high. Daily, 92 400 journeys take place in the Luxembourg part of the corridor.(Ministère de la Mobilité et des Travaux publics luxembourgeois, 2022)
- There is **no cycle highway** neither are there plans to build a cycle highway.
- Intermodality with public transport (bus or train) can be an interesting asset for people using the cycle highway. For Belgians it could be of interest to reach the first Luxemburg railway station in Kleinbettingen or busstop in Steinfort to continue their journey for free by train or bus. Public transport is free in Luxembourg.
- The **cycle connection** has an advantage over the actual Arlon-Luxemburg rail connection. It is **more flexible** than the rail connection that obliges people to go the Luxemburg railway station which is not close to all workplaces in the city of Luxemburg.
- As Luxemburg and Wallonia are regions where cycling is not popular at all **the cycle potential is enormous**. There is already an active and growing cycle group of people commuting regularly between Arlon and Luxembourg (Paul Fouguenne)
- Some mobility data are available from the Luxembourg Ministery .(Ministère de la Mobilité et des Travaux publics luxembourgeois, 2022). These data are of relatively good quality.

There are also reasons for **not choosing this link.** These can however be **refuted.** Below you find reasons for not choosing this link and how these reasons can be refuted:

- There is already a **good and well used rail link** between Arlon and Luxembourg. Car users willing to make a shift away from the car could prefer train above the bicycle.
    - Although cycling is more flexible than the train. Not all people work or live near the railway station.
- The building of a **cycle path is already foreseen** along the national road between Arlon and Luxemburg.
    - Although the cycle comfort and cycle safety will be higher along cycle highway which will in turn attract more cyclists (Amsterdam and other Dutch public authorities, Together we cycle, 2020).
- **Cycling is not popular** in Luxemburg and Wallonia. People will not use their bicycle to go
    - Cyclists will grow with infrastructure and positive actions in favour of cycling. Even in the Netherlands, the cycle culture is only there thanks to voluntary action in the seventies.
- **Speed pedelecs are not admitted** on cycle infrastructure in Luxemburg, while for distances over 15 km, speed pedelecs are the best guarantee for modal shift away from car.
    - Generally, most of the cycle travel is done with push bikes and "slow" pedelecs. In Flanders, a rather bicycle friendly region with a favourable legislative framework for speed pedelecs, only 0.5% of the bicycle park were speed pedelecs (Fietsberaad, 2019). On cycle highways, however, they appear more frequently. In Wilsele on the Leuven-Brussels cycle highway, 8% of cyclists used a speed pedelec (Kortenberg website, 2018).

      In Wallonia, speed pedelecs are today nearly non existent. Only 2% of Belgian Speed Pedelecs are registered in Wallonia (Fietsberaad, 2019) and among the Arlon-Luxembourg cyclists, no one uses a speed pedelec (Foguenne, 2022).
    - Also in Germany, speed pedelecs are not allowed on cycle highways. In spite of that ban for speed pedelecs, cycle highways are successful in Germany. Costs and benefits of the Arlon-Luxembourg cross border cycle highway.

- In other words, not admitting speed pedelecs won't limit the potential in the short term. In the longer term however, it could make sense to reconsider the interdiction for speed pedelecs on cycle highways and/or certain other cycle infrastructure without or with a speed limit.

5.2 Two alternative cycle highway routes between Arlon and Luxembourg selected among 4 alternatives

Four potential cycle routes between Arlon and Luxembourg

As said in the previous section, a growing number of people do the Arlon-Luxembourg commute very regularly by bicycle. Based on their experience, they wrote down their preferred routes between Arlon and Luxemburg. (Foguenne, 2022 and Arlon Cycling Club, 2022).

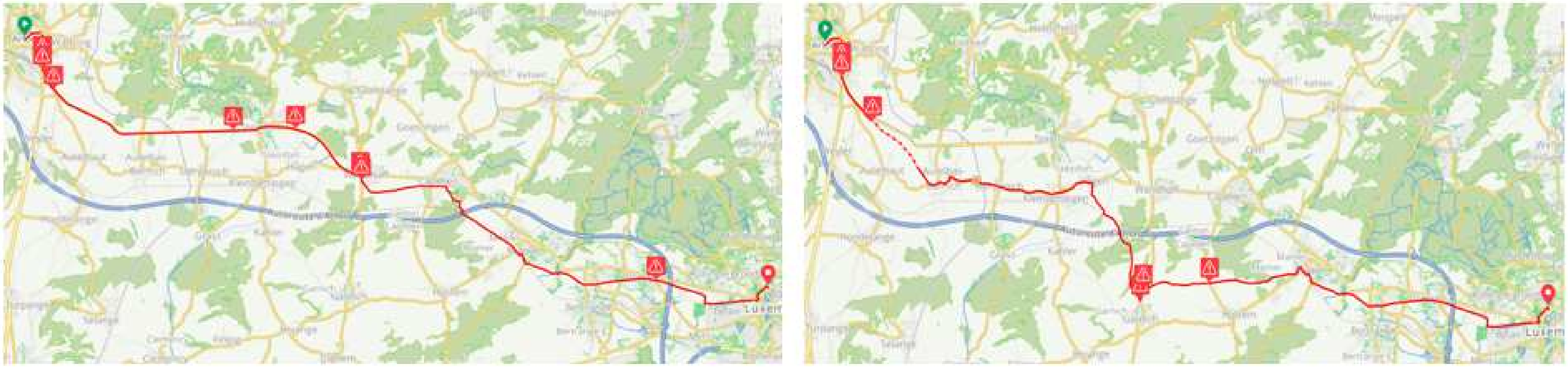
The maps below provide the three preferred cycle routes of the actual commuter cyclists. The fourth map, in the right below corner, shows an alternative for a new cycle highway along the railway line.

- Alternative 1 (Alt.1) on Figure 5-1 uses the cycle path on the national road Arlon Luxembourg (N4) on Belgian territory, the national road Arlon-Luxembourg (N6) in Luxemburg and joins then the PC14 (cycle path 14) in Capellen and PC13 (cycle path 14) in Mamer.
  This a fast road, but not very convenient as the cycle path is not well maintained in Belgium. In Luxembourg, cycle infrastructure is not always present, especially the crossing of Steinfort and some further passages remain dangerous or not adapted for cyclists.
- Alternative 2 (Alt.2) on Figure 5-1 uses a new nice agricultural road on Belgian territory and continues on rather quite Luxembourg routes and joins then the PC14 in Capellen and the PC13 in Mamer which are convenient cycle routes.
  This is a quite and convenient route preferred by the actual cyclists. It follows relatively close the national road where most of the travel potential is situated. It is also close to the public transport nodes, bus nodes along the national roads and train nodes along the railwayline.

- Alternative 3 (Alt.3) on Figure 5-1 is called the "nice weather" route. It is a bit less convenient for fast commuting with a bit more altimeters. It uses PC12 (cycle path 12) and PC 13 (cycle path 13).

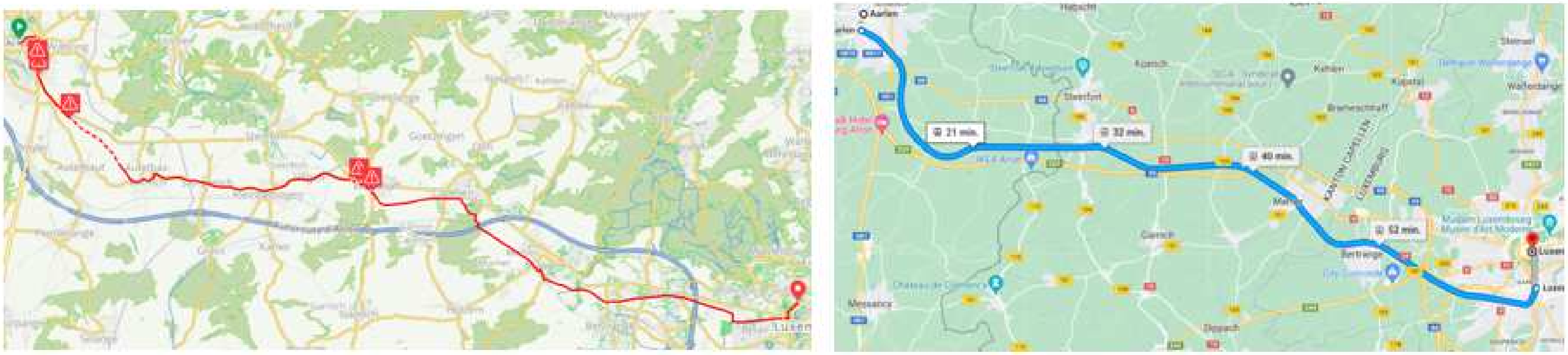
- Alternative 4 (Alt.4) on Figure 5-1 is a completely new cycle highway. We choose here to put it along the existing rail way line, but we could also have chosen another route. The important thing for the exercice here is that it is an alternative requiring new infrastructure.

We add also a general remark on the Luxembourg cycle paths. They often contain some sharp turns which are not acceptable on a cycle highway. Pedestrians are also often present on the cycle paths which can sometimes cause dangerous situations.



Alt.1: N4–N6–PC13 https://ridewithgps.com/routes/40718977

Alt.3: PAC agri-PC12-PC13 https://ridewithgps.com/routes/40719056



Alt.2: PC agri–PC14-PC13 https://ridewithgps.com/routes/40718857

Alt.4:New route along the railwayline Arlon-Luxembourg

Figure 5-1: maps with the alternative routes between Arlon and Luxembourg (source Paul Foguenne, 2022)

The link below the maps provides the web link to more information on the routes. You find there a detailed map with the precise distance and the altitude profile. Each map also provides the "dark points" with unsafe and or inconvenient passage for the cyclist with a red flag.

Most often, quite simple interventions can remedy to the dark points and make the route much safer and convenient for the cyclist. For example for alternative 2, the maps indicate two dangerous points around Wandhaff. For the first one, making a dirt track usable for cyclists would enable them to avoid a dangerous crossing and for the second one a crossing would need a safer design.

The table below summarises the characteristics and the advantages and the disadvantages of each of the four cycle highway route alternatives.

	Alternatives for cycle highway Arlon Luxembourg			
	1	2	3	4
	N4-N6-PC13	PC agri-PC13	PC agri-PC12-PC13	new railway
distance (km)	27	29	29	27
altimeters	+153, -263	+170,-280	+209,-318	
positive	*shortest *fastest *cleanest in winter *close to road corridor with potential	*most used *easy to realise improvements *close to road corridor with potential *connection with town of Steinfort via PC12	*nice weather route	*best infrastructure *intermodality (railway stations)
negative	*N4; lack of maintenance *Steinfort passing difficult to arrange *PC14-PC13, some sharp turns to adapt *PC14-PC13 presence of pedestrians	*some improvements necessary *PC14-PC13, some sharp turns to adapt *PC14-PC13 presence of pedestrians	*some improvements necessary *PC12-PC13, some sharp turns to adapt *PC12-PC13 presence of pedestrians	*expensive *further from road corridor with higher potential

Table 5.2: characteristics of four alternative cycle highway routes

Alternative 2 and Alternative 4 selected

To move on, we select two alternatives to study in a more detail, the alternative 2 and alternative 4. The interest of selecting these two alternatives is that there is an alternative starting from the existing infrastructure and an alternative building complete new infrastructure. The alternative 2 is the preferred among the actual cyclists, it avoids the inconvenient national road, it allows intermodality with bus and train and it limits the altimeters.

5.3 What are the costs for the building of the cycle highway?

Within this project we took simplified assumptions to determine the costs.

Infrastructure costs can be subdivided in investment and maintenance costs. Below we make assumptions on the investment costs. The maintenance costs are included in the costs for the different modes we use for the calculation of the benefits. So, we make no particular assumptions on the maintenance costs in this section.

For alternative 2, based on the upgrade of existing infrastructure, we assume that the upgrade is possible with a cost of 100 000 EUR/ km.

Following the ECF paper (ECF, 2021) , 50 000 EUR/km is the cost for a simple cycle track in easy terrain. 200 000 EUR/km is the cost for mixed solutions and localisations with some challenges to overcome. The most recent figure from the Walloon administration is 195 000 EUR/km for a 1.75 m cycle path in easy terrain.

For the alternative 2, on the major part of the route, relatively good infrastructure is available that is however often too small with too sharp turns. Based on information from the Luxemburg Mobility and Public Works Administration, actual cycle paths are in between 2.5m and 3.5 m wide. In our assumptions, we leave the 3.5m wide paths as that and will only upgrade the 2.5m wide paths. Also some crossings will need revision, some streets will need to be turned into cycle streets and turns will need to be made larger. The 100 000 EUR/km assumption looks us reasonable therefore. Based on this assumption, total investment costs are 2.9 million EUR.

For the alternative 4, the new infrastructure, we use a cost of 750 000 EUR/km.

This figure is based on different sources:

- Beukers (Beukers, 2015). Beukers and his colleagues analysed the costs for the Antwerp-Mechelen cycle highway and came up with a cost in between 300 000 and 800 000 EUR/km. Taken into account that the relief in the Arlon-Luxembourg area we could count with a weigted average where 300 000 EUR counts for 1/3 and the 800 000 EUR counts for 2/3. Taking into account the inflation we could count with a km cost of 760 000 EUR/km.
- ECF (ECF 2021) estimates the cost of a cycle highway at 500 000 EUR/km in easy terrain, and 1.500 000 EUR/km for a standard cycle highway in an urban area.
- The average cost of the Copenhagen Cycle Superhighways is estimated at 400 000 EUR/km, following the EC cycle highway website.
- The British cycle highways built as part of the Cycle City Ambition range from 840 000 EUR/km to 1 640 000 EUR/km following the EC cycle highway website.
- Mr Trilllet from the Walloon roadadministration count with figures of 195 EUR/m for a 1.75 m wide cyclepath and 247 EUR/m for a 2.5 m cycle path in rural areas in easy terrain. These figures take into account a 30% increase due to recent environmental standards concerning removal of soil. For a 4 m wide cycle highway we assume the cost would then be around 350 EUR/m (350 000 EUR/km). We calculated the latter figure based on the

assumption that for a 60% increase in width (from 2.5 to 4m) an increase in costs of 40% seems reasonable.

We use a figure, 750 000 EUR/km at the higher end of these estimates as the cycle highway is to be built in a region that is sloping. Based on this assumption total investment costs are 27 million EUR.

	Alt. 2	Alt. 4
	PC agri-quite roads PC14-PC13	new, along railwayline
cost (EUR)/km	100 000	750 000
total building cost (million EUR)	2.9	20.3

Table 5.3:assumed building costs for the alternatives

In this simplified analysis we did not take into account the eventual losses in consumer surplus from people that change modes.

5.4 What are the benefits of building the cycle highway?

Also to determine the benefits, as for the costs, we make simplified assumptions due to the limited resources available in the project.

To calculate the benefits of the cycle highway, we will first calculate the benefits per km cycled on the new cycle highway (section 5.4.1). Then we multiply the benefit per km by the amount of km cycled during the cycle highway lifetime, 30 years.(section 0)

To determine the total amount of km cycled during the lifetime, we calculate the expected km cycled in 2035, derive the expected km cycled km during each year of the period and discount the km cycled. “Discounting” is the economic word for adapting values for the fact that gains and costs situated further in the future are less worth than costs and gains today. A km cycled in the future has therefore less value than a kilometre cycled today.

Changes in consumer surpluses have not been taken into account.

5.4.1 Benefits per km cycled

The benefits are generated by the new cyclists and the possible time gains of the actual cyclists. Concerning the new cyclists, the gains are different depending on whether the new cyclists would use a car, public transport (PT), be pedestrian or not make the journey.

The average gain per cycle km is 1.20 EUR based on the below assumptions.

		gains/EUR km			
	share	**20%/80%**	B	L	
new cyclists, car driver if not cyclist	**25%**				
push bike	16%	2.37	1.86	2.49	**car L**
e-bike	9%	1.49	1.11	1.59	
speed pedelec	0%	0.90	0.66	0.96	
new cyclist, PT user if not cyclist	**45%**				
push bike	29%	1.63	1.40	1.68	**average bus and train L**
e-bike	16%	0.75	0.65	0.77	
speed pedelec	0%	0.50	0.21	0.57	
new cyclists, pedestrian if not cyclist	**5%**				
push bike	10%				
e-bike	5%				
speed pedelec	0%				
new cyclist, not making the journey if not cycling	**10%**				
push bike	7%	1.20	0.90	1.27	
e-bike	4%	0.32	0.15	0.36	
speed pedelec	0%	-0.27	-0.30	-0.27	
actual cyclist gaining time	**15%**				
push bike	10%				
e-bike	5%				
speed pedelec	0%				
weigthed average of cycle km		1.20			
push bike	**65%**				
e-bike	**35%**				
speed pedelec	**0%**				

Table 5.4:calculation of the average value of a km cycled

		gains/EUR km			
	share	**20%/80%**	B	L	
new cyclists, car driver if not cyclist	**25%**				
push bike	16%	2.37	1.86	2.49	**car L**
e-bike	9%	1.49	1.11	1.59	
speed pedelec	0%	0.90	0.66	0.96	
new cyclist, PT user if not cyclist	**45%**				
push bike	29%	1.63	1.40	1.68	**average bus and train L**
e-bike	16%	0.75	0.65	0.77	
speed pedelec	0%	0.50	0.21	0.57	
new cyclists, pedestrian if not cyclist	**5%**				
push bike	10%				
e-bike	5%				

speed pedelec	0%				
new cyclist, not making the journey if not cycling	**10%**				
push bike	7%	1.20	0.90	1.27	
e-bike	4%	0.32	0.15	0.36	
speed pedelec	0%	-0.27	-0.30	-0.27	
actual cyclist gaining time	**15%**				
push bike	10%				
e-bike	5%				
speed pedelec	0%				
weigthed average of cycle km		1.20			
push bike	**65%**				
e-bike	**35%**				
speed pedelec	**0%**				

Table 5.4 shows the assumptions in bold and the calculation to determine the average value of a km cycled. The assumptions are further explained below.

Assumptions on the mode chosen in the absence of the cycle highway

We assume that, in the absence of the cycle highway

- 25% of the extra cycle km would be driven by car
- 45% of the extra cycle km would of the extra cycle PT
- 5% of the extra cycle km would be a pedestrian
- 10% of the extra cycle km would not have been made

15% of the extra cycle km was already made before the building of the cycle highway

These figures are inspired by the figures used in the study on the impact and the potential of cycling in the Brussels Capital region (Van Zeebroeck, 2014) and adapted based on other sources and our expert judgment.

- The share of cyclists that would driving cars remains the same at 25%. It takes into account two sources with opposing results.
  - The impact of the use of e-bikes, nearly not present in 2014. E-bikes and speed pedelecs facilitate the shift from car to bicycle with pedelecs replacing up to 35% carkm and speed pedelecs up to 50%. (Cairns, 2017) (Fietsberaad, 2020) (SWOV, 2017) (SVI, 2017).
  - The Danish bicycle highway account observed that on average 14% of new cyclists used previously a car. The figure varies between 10 and 26% depending on the cycle highway (Office for bicycle highways, 2019).
- The share of cyclists that would use public transport is set at 45%, instead of 60% in the 2014 Van Zeebroeck study. We decreased the share as we are not in an urban context.
- The share of cyclists that would be pedestrians is decreased, from 10% to 5% taking into account that we are not in an urban context.
- We estimated the share of cyclists that would not make the journey if the cycle highway would not be available at 10%. This estimate is based on the BiTiBi project were around 10% would not have made the trip in the absence of an improved public

transport service with a possibility to use a bicycle for the last mile (BiTiBi, 2017). These services are quite different, although similar in the fact that they provide an improvement to an existing journey possibility /

- We estimate furthermore at 15% the share of 2035 cyclists already present in 2017. 15% equals 1%(2017) over 7% (2035).

Assumptions on the shares by bicycle type

- 65% of cyclists use a push bike on the bicycle highway
- 35% of cyclists use an e-bike

These figures are based on a counting on the Leuven-Brussels bicycle highway. Approximately 65% were made by push bikes among which 30% city bikes and 35 % race- and mountainbikes, 25% by e-bikes and 10% by speed pedelecs. We increased the number of e-bikes and set the share of speed pedelecs at 0.

Assumptions to determine the values of bicycle km

To determine the value of bicycle km for the different categories of cyclists we take some further assumptions. For the different types of cyclists we calculate a value of a cycle km driven by a Belgian and a Luxembourger. We assume furthermore that among the cyclist on the cycle highway, 20% will be Belgian and 80% Luxembourger. The cost and benefits values are taken from part Chapter **Error! Reference source not found.**.

- For the new cyclists that would be car drivers in the absence of the cycle highway, we calculated the difference between the societal value of the push bike and the car. For car we always use the Luxembourg car value as the most important value in the car cost it congestion and nearly all congestion in the Luxembourg-Arlon corridor is situated in the country of Luxembourg.
- For the new cyclists that would be PT users, the PT cost are an average of Luxembourg bus and train costs as the major part of the PT will be Luxembourg PT.
- For the new cyclists that would be pedestrians, we do not take gains or costs into account. We do not have precise figures for costs of pedestrians and we assume the health benefits of walking are in the same order of magnitude taken into account that both are active modes.
- We have not been calculating the value of time gained by the actual cyclists thanks to the new cycle highway.

We finally arrive at a figure of 1.20 EUR/cycle km.

5.4.2 *Total amount of cycle km over the 2025-2055 period.*

To calculate the extra km cycled, we first calculate the extra km cycled in 2035. Then we calculate the amount of km cycled expected in the 2025-2055 period, which we assume the lifetime of the cycle highway. Finally, we discount the expected km cycled to a today value.

Between 2.5 and 5.0 million extra cycle km in 2035

	2017		2035	
% and number of trips per day				
total in corridor Arlon-Luxembourg	100%	140000		189000
internal to corridor Arlon-Luxembourg	30%	42000	30%	56700
to or from Lux or suburban ring	36%	50400	36%	68040
total		92400		124740
cycle share and cycle trips per day in the corridor area				
cycle share in	1%	924	7%	8732
in the cycle highway area	1%	499	54%	4700
dutch cycle share in 2019			28%	34927
in the cycle highway area			54%	18800
increase in cycle trips by 2035 compared to 2017				
foreseen in mobility plan			7%	4201
if cycling like Dutch in 2019			28%	18301
share of increase in cycle trips attributed to cycle highway				
with 7% modal share (transport plan Luxembourg)				
cycle highway effect in mature cycle countries			4%	168
assumption Luxembourg moderate			20%	840
assumption Luxembourg high			40%	1680
with 28% modal share (like Dutch in 2019)				
cycle highway effect in mature cycle countries			4%	732
assumption Luxembourg moderate *			20%	3660
assumption Luxembourg high *			40%	7320
100 000 km cycled with average cycled distance 8 km/day - 200 days/year				
with 7% modal share (transport plan Luxembourg)				
highway effect in mature cycle countries			4%	3
assumption Luxembourg moderate			20%	13
assumption Luxembourg high			40%	27
with 28% modal share (like Dutch in 2019)				
highway effect in mature cycle countries			4%	12
assumption Luxembourg moderate			20%	59
assumption Luxembourg high			40%	117

Table 5.5: estimate of extra km travelled in 2035 thanks to cycle highway

The table above provides estimates of the extra km cycled based on a simplified method explained below.

Total amount of journeys

To calculate the extra km cycled in 2035 thanks to the cycle highway, the table starts from the total number of trips in 2017 and 2035 with an origin or destination in the corridor Arlon-Luxemburg corridor between Luxembourg and the border with Belgium. The number of journeys in the corridor we will take into account is the sum of the journeys in the corridor (30% of total) and the journeys from the corridor to Luxembourg city (36% of total). We obtain this information from the National Mobility Plan of Luxembourg. (Ministère de la Mobilité et des Travaux publics luxembourgeois, 2022). It consists of 92 400 daily trips in 2017 and 124740 in 2035.

Between 4 200 and 18 300 extra daily cycle trips in 2035

We then calculate the increase in cycle trips between 2017 and 2035. Therefore we first calculate the share of cycle trips among these trips based on two hypothesis. The first hypothesis assumes a cycle share 7% cycling in 2035 as foreseen in the Luxembourg mobility plan. This leads to 8 732 daily cycle trips in the corridor. The second hypothesis assumes a cycle share of 28% cyclists in 2035. This is the equivalent of the today cycling share in the Netherlands (CBS, 2022). This leads to 34 927 daily cycle trips in the corridor. However, only part of these trips are close enough to the cycle highway to use that highway in the future. Based on a conversation with the Luxemburg Public Works Ministery, slightly more than half (54%) of these trips will use the cycle highway. The increase in daily cycle trips compared to 2017 is then 4201 for the 7% modal share in 2035 and 18 301 for the 28% modal share.

Between 150 and 7300 daily cycle trips attributable to the cycle highway

Then we make an assumption on the share of cyclists that start cycling thanks to the presence of the cycle highway. It would be a strong exaggeration that all new cyclists foreseen in the mobility plan will all be there thanks to the new infrastructure. Other measures will be necessary to convince people to take their bicycle. We work with 4 scenario's concerning the share of cycle trips that can be attributed to the new infrastructure, a 4%, a 20% and a 40% scenario.

- 4% of the increase is attributable to the construction of the cycle highway. This figure is based on a Dutch and a Danish paper (Macedo, 2022 and Hans, 2017) and is thus a figure for countries with a well-established cycle culture. The papers observed the number of cyclists on new cycle highways. They observe that a lot of people use the new cycle highway, although a large majority of those cycled also in the past, using other routes. The new route is simply more convenient. A minority consist of new users. The papers conclude that 4 to 5% of the users of the cycle highway are new cyclists that didn't cycle before.
- 20% of the increase is attributable to the construction of the cycle highway. We believe that in countries where cycling is not yet established as it is in the Netherlands or Denmark, the potential for attracting new cyclists via new infrastructure is larger. We take a 20% (this scenario) and a 40% scenario (the next scenario).
- 40% of the increase is attributable to the construction of the cycle highway

The combination of the 28% Dutch modal share with shares of 20% and 40% of the increase attributable to the cycle highway are greyed and written in a smaller letter type. The reason is that these are less straightforward assumptions. One could argue that once Luxemburg reaches 28% cycle modal shares, Luxemburg is a developed cycle country and therefore the 20% or 40%

assumptions make no sense. Other people could although argue that to reach this 28% Dutch modal share, it makes sense to count with the 20% and 40% assumptions.

These different scenario's in combination with the 7% and 28% modal share come up with in between 168 and 7320 extra cycle trips that can be attributed to the cycle highway.

Between 0.3 and 12 million extra yearly cycle km thanks to the cycle highway in 2035

We then translate the cycle trips into yearly cycle km. Therefore we assume then that the average distance travelled on the cycle highway is 8 km and that the trips are made 200 days a year. The extra km travelled in 2035 is then, depending on the hypothesis, between 0.3 and 12 million km/year.

The average 8 km trip distance assumption is hard to make as sources go in different directions.

- The average cycle distance per trip is the Netherlands is 4 km (CBS, 2022)[33]
- The average cycling distances in Flanders is longer with 5.4 and 6.7 km for the commuting trips (VRT, 2015).
- Distances on a cycle highway seem however to be much longer. The average cycling distance on the Leuven-Brussels cycle highway was 22.8 km in 2018 (Vlaams Brabant, 2018).
- Average distances on the cycle highways in the Capital Region Denmark vary between 6.4 and 14.7 km/trip, with an overall average of 11 km/trip (Office for Bicycle Highways, 2019)

Taking into account the longer cycle distance on the Leuven-Brussels cycle highway and the Danish cycle highways, we judge an average cycle distance on the Arlon-Luxembourg of 8 km as reasonable.

Km cycled over the 2025-2055 period

The next step is then to translate the 2035 yearly extra cycle km in a total amount of extra km over a 30 year period, lets's say between 2025 and 2055. A 30 years period is a realistic lifetime for the cycle

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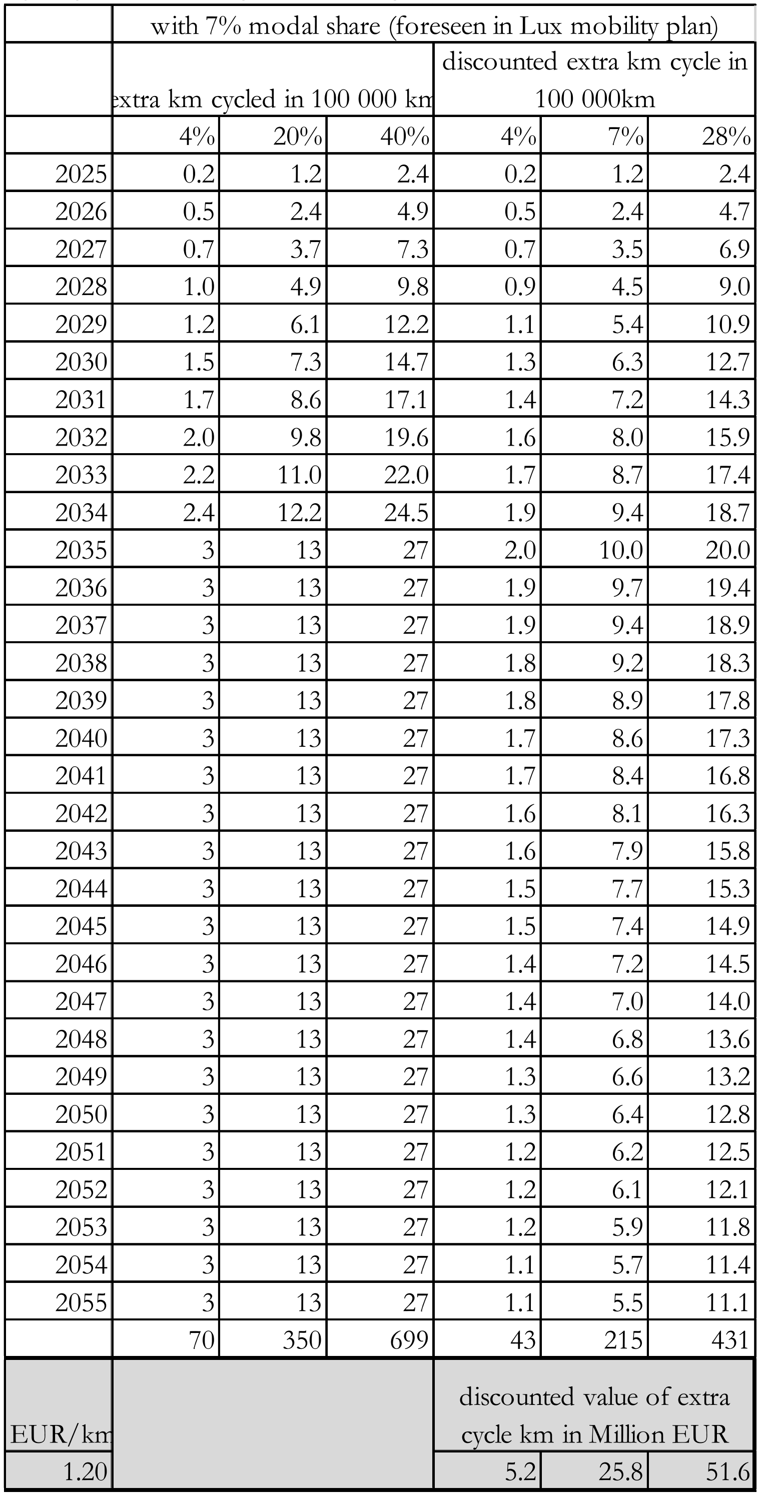
[33] https://www.cbs.nl/nl-nl/longread/rapportages/2021/onderweg-in-nederland--odin---2020-plausibiliteitsrapportage/5-gemiddelde-afgelegde-afstand-per-verplaatsing

highway infrastructure (Beukers, 2014).



	with 7% modal share (foreseen in Lux mobility plan)					
	xtra km cycled in 100 000 kn			discounted extra km cycle in 100 000km		
	4%	20%	40%	4%	7%	28%
2025	0.2	1.2	2.4	0.2	1.2	2.4
2026	0.5	2.4	4.9	0.5	2.4	4.7
2027	0.7	3.7	7.3	0.7	3.5	6.9
2028	1.0	4.9	9.8	0.9	4.5	9.0
2029	1.2	6.1	12.2	1.1	5.4	10.9
2030	1.5	7.3	14.7	1.3	6.3	12.7
2031	1.7	8.6	17.1	1.4	7.2	14.3
2032	2.0	9.8	19.6	1.6	8.0	15.9
2033	2.2	11.0	22.0	1.7	8.7	17.4
2034	2.4	12.2	24.5	1.9	9.4	18.7
2035	3	13	27	2.0	10.0	20.0
2036	3	13	27	1.9	9.7	19.4
2037	3	13	27	1.9	9.4	18.9
2038	3	13	27	1.8	9.2	18.3
2039	3	13	27	1.8	8.9	17.8
2040	3	13	27	1.7	8.6	17.3
2041	3	13	27	1.7	8.4	16.8
2042	3	13	27	1.6	8.1	16.3
2043	3	13	27	1.6	7.9	15.8
2044	3	13	27	1.5	7.7	15.3
2045	3	13	27	1.5	7.4	14.9
2046	3	13	27	1.4	7.2	14.5
2047	3	13	27	1.4	7.0	14.0
2048	3	13	27	1.4	6.8	13.6
2049	3	13	27	1.3	6.6	13.2
2050	3	13	27	1.3	6.4	12.8
2051	3	13	27	1.2	6.2	12.5
2052	3	13	27	1.2	6.1	12.1
2053	3	13	27	1.2	5.9	11.8
2054	3	13	27	1.1	5.7	11.4
2055	3	13	27	1.1	5.5	11.1
	70	350	699	43	215	431
EUR/kn				discounted value of extra cycle km in Million EUR		
1.20				5.2	25.8	51.6

Table 5.6 provides an overview of the future km cycled for the scenario with 7% modal share in 2035.

	with 7% modal share (foreseen in Lux mobility plan)					
	xtra km cycled in 100 000 km			discounted extra km cycle in 100 000km		
	4%	20%	40%	4%	7%	28%
2025	0.2	1.2	2.4	0.2	1.2	2.4
2026	0.5	2.4	4.9	0.5	2.4	4.7
2027	0.7	3.7	7.3	0.7	3.5	6.9
2028	1.0	4.9	9.8	0.9	4.5	9.0
2029	1.2	6.1	12.2	1.1	5.4	10.9
2030	1.5	7.3	14.7	1.3	6.3	12.7
2031	1.7	8.6	17.1	1.4	7.2	14.3
2032	2.0	9.8	19.6	1.6	8.0	15.9
2033	2.2	11.0	22.0	1.7	8.7	17.4
2034	2.4	12.2	24.5	1.9	9.4	18.7
2035	3	13	27	2.0	10.0	20.0
2036	3	13	27	1.9	9.7	19.4
2037	3	13	27	1.9	9.4	18.9
2038	3	13	27	1.8	9.2	18.3
2039	3	13	27	1.8	8.9	17.8
2040	3	13	27	1.7	8.6	17.3
2041	3	13	27	1.7	8.4	16.8
2042	3	13	27	1.6	8.1	16.3
2043	3	13	27	1.6	7.9	15.8
2044	3	13	27	1.5	7.7	15.3
2045	3	13	27	1.5	7.4	14.9
2046	3	13	27	1.4	7.2	14.5
2047	3	13	27	1.4	7.0	14.0
2048	3	13	27	1.4	6.8	13.6
2049	3	13	27	1.3	6.6	13.2
2050	3	13	27	1.3	6.4	12.8
2051	3	13	27	1.2	6.2	12.5
2052	3	13	27	1.2	6.1	12.1
2053	3	13	27	1.2	5.9	11.8
2054	3	13	27	1.1	5.7	11.4
2055	3	13	27	1.1	5.5	11.1
	70	350	699	43	215	431
EUR/km				discounted value of extra cycle km in Million EUR		
1.20				5.2	25.8	51.6

Table 5.6: overview of future km cycled with for the scenario with 7% modal cycle share in 2035 and the discounted values.

For the years between 2025 and 2035 we assume a linear increase of the km cycled. After 2035 we assume that the cycle km do no longer increase. The estimated yearly km cycled are provided in the left hand side columns in the table.

We then discount the future cycle km. The reason is that future gains (or losses) are less valued compared to actual gains (or losses). We count with a discount rate of 3%. This is the recommended discount rate in the EU for road transport projects.[34] With a discount rate of 3%, the km cycled in 2055 values only 41% of the km cycled in 2025. Discounting is done in the right hand side columns in the table.

Value of the km cycled over the 2025-2055 period

The last step in valuing the benefits consists then in multiplying the cycled km by the value of these.

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[34] https://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/cba_guide.pdf

The result	*can be seen in the lower right corner of* with 7% modal share (foreseen in Lux mobility plan)					
	xtra km cycled in 100 000 k			discounted extra km cycle in 100 000km		
	4%	20%	40%	4%	7%	28%
2025	0.2	1.2	2.4	0.2	1.2	2.4
2026	0.5	2.4	4.9	0.5	2.4	4.7
2027	0.7	3.7	7.3	0.7	3.5	6.9
2028	1.0	4.9	9.8	0.9	4.5	9.0
2029	1.2	6.1	12.2	1.1	5.4	10.9
2030	1.5	7.3	14.7	1.3	6.3	12.7
2031	1.7	8.6	17.1	1.4	7.2	14.3
2032	2.0	9.8	19.6	1.6	8.0	15.9
2033	2.2	11.0	22.0	1.7	8.7	17.4
2034	2.4	12.2	24.5	1.9	9.4	18.7
2035	3	13	27	2.0	10.0	20.0
2036	3	13	27	1.9	9.7	19.4
2037	3	13	27	1.9	9.4	18.9
2038	3	13	27	1.8	9.2	18.3
2039	3	13	27	1.8	8.9	17.8
2040	3	13	27	1.7	8.6	17.3
2041	3	13	27	1.7	8.4	16.8
2042	3	13	27	1.6	8.1	16.3
2043	3	13	27	1.6	7.9	15.8
2044	3	13	27	1.5	7.7	15.3
2045	3	13	27	1.5	7.4	14.9
2046	3	13	27	1.4	7.2	14.5
2047	3	13	27	1.4	7.0	14.0
2048	3	13	27	1.4	6.8	13.6
2049	3	13	27	1.3	6.6	13.2
2050	3	13	27	1.3	6.4	12.8
2051	3	13	27	1.2	6.2	12.5
2052	3	13	27	1.2	6.1	12.1
2053	3	13	27	1.2	5.9	11.8
2054	3	13	27	1.1	5.7	11.4
2055	3	13	27	1.1	5.5	11.1
	70	350	699	43	215	431
EUR/km				discounted value of extra cycle km in Million EUR		
1.20				5.2	25.8	51.6

Table 5.6. Depending on the scenario, the discounted future societal benefits lie between 5.2 and 51.6 million EUR.

5.5 What is the cost benefit ratio for building the cycle highway?

With the costs and benefits calculated in the previous sections, we can now calculate cost benefit ratios for the different scenarios.

Upgrading thoroughly the existing infrastructure provides 9 times more benefits than costs in the most probable scenario

	with 7% modal share (transport plan Luxembourg)					
	Alt 2 (improving existing)			Alt 4 (new infra)		
	share of increase in cycle trips attributed to cycle highway			share of increase in cycle trips attributed to cycle highway		
	4%	20%	40%	4%	20%	40%
cost (M Eur)	2.9	2.9	2.9	20.25	20.25	20.25
benefit (M Eur)	5.1	25.7	51.4	5.1	25.7	51.4
benefit/cost	1.8	8.9	17.7	0.3	1.3	2.5
	with 28% modal share (like Dutch in 2019)					
	Alt 2 (improving existing)			Alt 4 (new infra)		
	4%	20%	40%	4%	20%	40%
cost (M Eur)	2.9	2.9	2.9	20.25	20.25	20.25
benefit (M Eur)	22.4	112.0	223.9	22.4	112.0	223.9
benefit/cost	7.7	38.6	77.2	1.1	5.5	11.1

Table 5.7: overview of cost and benefits for different scenario's

Table 5.7 shows the costs, the benefits and the benefit/cost ratio for different scenario's. The upper part of the table concerns the scenario where the cyclists modal share increases to 7% in 2035 and remains constant the following years. The lower part of the table concerns the scenario where cyclists modal share increases to 28% in 2035 and remains constant the following years.

The left hand side of the table concerns alternative 2, improving the existing infrastructure taking into account a cost of 100 000 EUR/km. The right hand side of the table concerns alternative 4, the building of a completely new infrastructure at a cost of 1 000 000 EUR/km.

The greyed figures are less straightforward for the reasons explained in section 5.4.2.

Within each infrastructure alternative, we have 3 scenario's concerning the cyclists attributable to the building of the infrastructure, 4%, 20% or 40%.

The benefits are logically bigger with more cyclists (a Dutch modal share of 28%) and more cyclists attributed to the building of the infrastructure (40% column). The scenario with the biggest benefits provides 224 million EUR benefits. The scenario with the lowest benefits provides 5.1 million EUR benefits.

Compared to the costs of the alternative 2 improved infrastructure, the benefits (5.1 M EUR) are still 80% superior to the costs (2.9 M EUR) in the most pessimistic scenario. In the most probable scenario, benefits are nearly 9 times higher than benefits. In the most positive case, the benefits are more than 70 times the costs.

Based on a simplified calculation, approximately 75% of the benefits are healthbenefits, 10% avoided congestion and 15% other benefits.

Error! Reference source not found. illustrates costs and benefits for alternative 2 graphically.

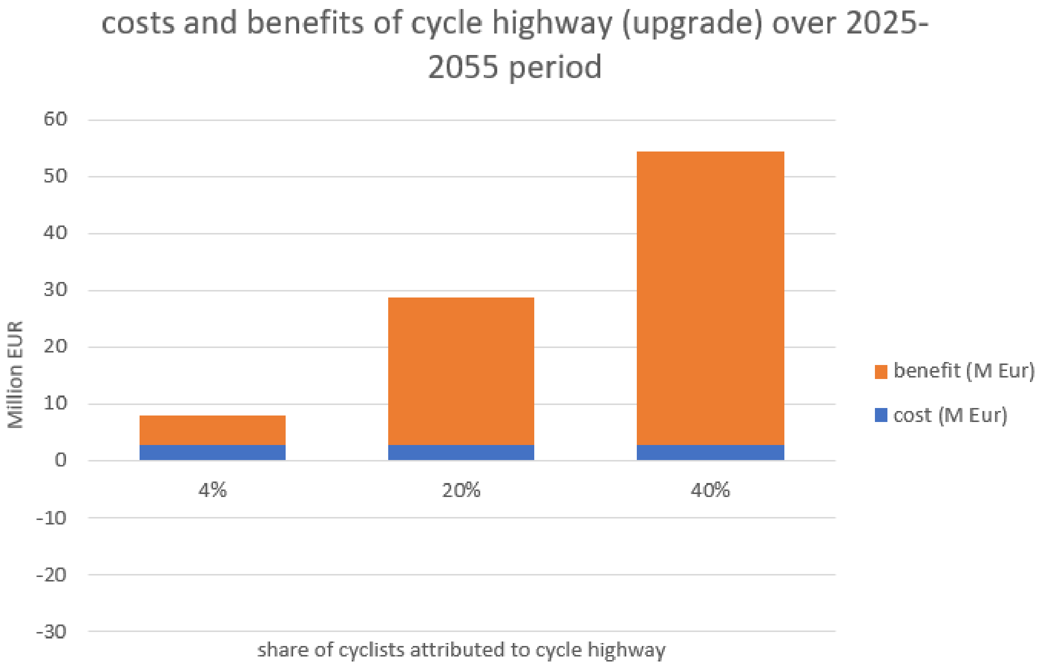
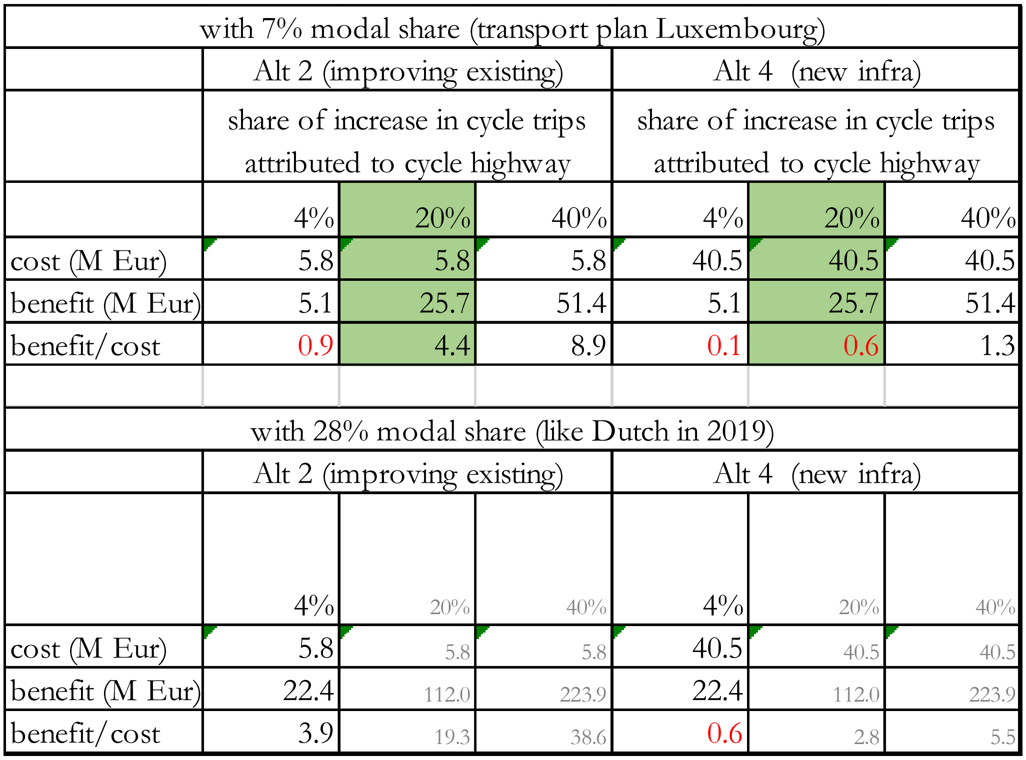


Figure 5-2: Benefits and costs of upgrade of the cycle highway (alternative 2) in the 2025-2055 period with a 7% cycle modal share

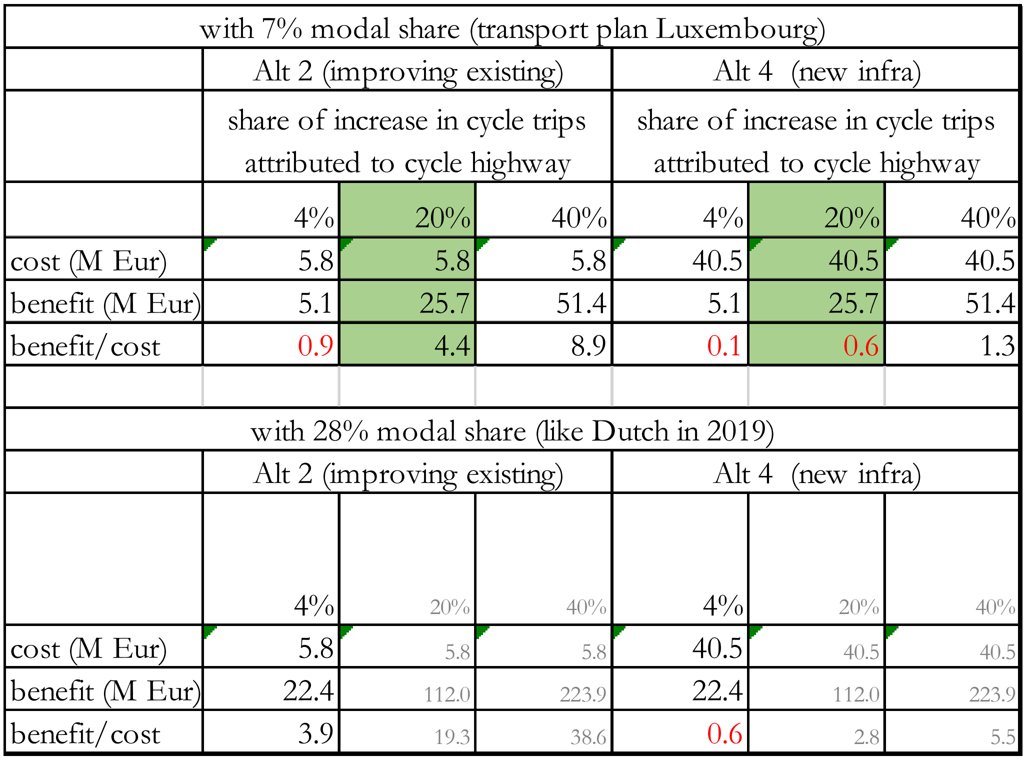
The ratios for the alternative 4 new infrastructure are less favourable. This is logic as the cost is nearly 10 times higher. In the scenario where only 4% of the new cyclists are attributed to the cycle highway and the cycle modal share is not bigger than 7%, the benefits are less than half the costs. Another important element is that when building the new infrastructure, part of the cyclists will still use the existing infrastructure. The benefits will therefore be lower than the benefits taken into account today. It is however difficult to estimate the share of cyclists that will prefer the existing infrastructure.

Even with a cost that is double, thoroughly upgrading the existing infrastructure generates benefits 4 times larger than costs in the most probable scenario



with 7% modal share (transport plan Luxembourg)						
	Alt 2 (improving existing)			Alt 4 (new infra)		
	share of increase in cycle trips attributed to cycle highway			share of increase in cycle trips attributed to cycle highway		
	4%	20%	40%	4%	20%	40%
cost (M Eur)	5.8	5.8	5.8	40.5	40.5	40.5
benefit (M Eur)	5.1	25.7	51.4	5.1	25.7	51.4
benefit/cost	0.9	4.4	8.9	0.1	0.6	1.3
with 28% modal share (like Dutch in 2019)						
	Alt 2 (improving existing)			Alt 4 (new infra)		
	4%	20%	40%	4%	20%	40%
cost (M Eur)	5.8	5.8	5.8	40.5	40.5	40.5
benefit (M Eur)	22.4	112.0	223.9	22.4	112.0	223.9
benefit/cost	3.9	19.3	38.6	0.6	2.8	5.5

Table 5.8: overview of costs and benefits for different scenario's with a doubling of the costs, 200 000 EU/km for improving the existing and 1 500 000 EUR/km for the new infra.

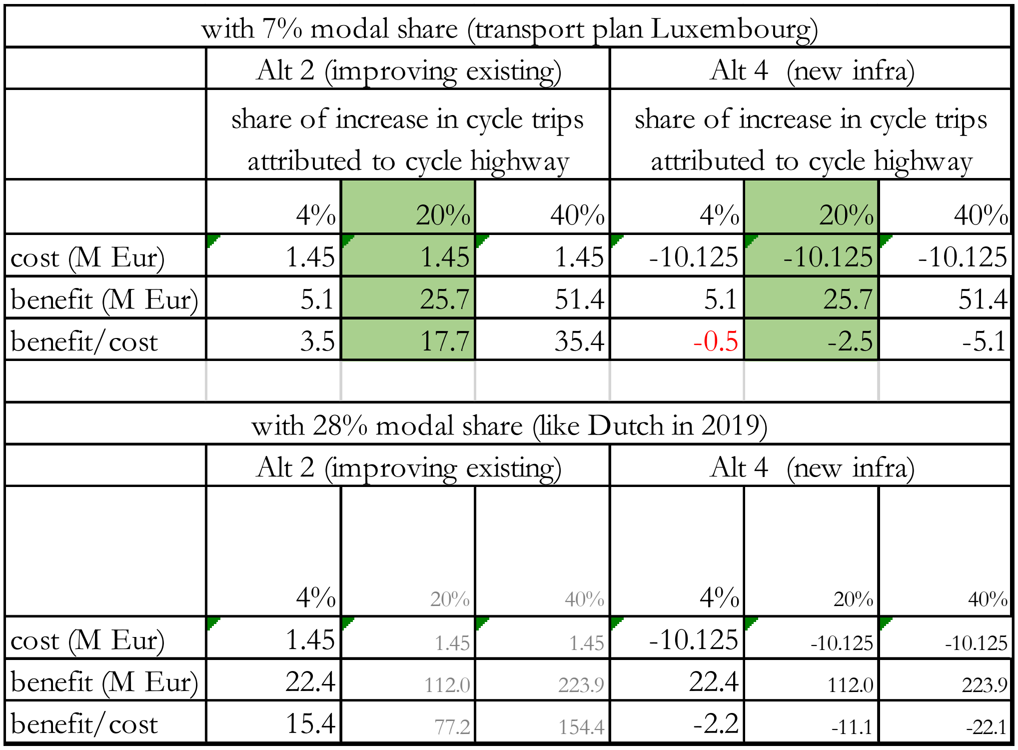


with 7% modal share (transport plan Luxembourg)						
	Alt 2 (improving existing)			Alt 4 (new infra)		
	share of increase in cycle trips attributed to cycle highway			share of increase in cycle trips attributed to cycle highway		
	4%	20%	40%	4%	20%	40%
cost (M Eur)	5.8	5.8	5.8	40.5	40.5	40.5
benefit (M Eur)	5.1	25.7	51.4	5.1	25.7	51.4
benefit/cost	0.9	4.4	8.9	0.1	0.6	1.3
with 28% modal share (like Dutch in 2019)						
	Alt 2 (improving existing)			Alt 4 (new infra)		
	4%	20%	40%	4%	20%	40%
cost (M Eur)	5.8	5.8	5.8	40.5	40.5	40.5
benefit (M Eur)	22.4	112.0	223.9	22.4	112.0	223.9
benefit/cost	3.9	19.3	38.6	0.6	2.8	5.5

Table 5.8 provides similar figures as Table 5.7. The only difference is that costs are doubled to 200 000 EUR/km for the alternative 2 scenario's and 1 500 000 EUR/km for the alternative 4 scenario's.

Logically, the benefit over cost ratios are halved. In spite of this, 2 out of 3 upgrade scenario's remain positive. Only the pessimistic scenario that attributes only 4% of the new cyclists to the cycle highway gets costs that are slightly higher than benefits. For the alternative 4 scenario's, two of them get negative. This is not surprising as the cost is really important with 1 500 000 EUR/km.

For completeness we still provide benefit over cost ratio's with costs that are halved compared to the initial table. This means 50 000 EUR/km for the alternative 2 and 375 00 000 EUR/km for the alternative 4.



with 7% modal share (transport plan Luxembourg)						
	Alt 2 (improving existing)			Alt 4 (new infra)		
	share of increase in cycle trips attributed to cycle highway			share of increase in cycle trips attributed to cycle highway		
	4%	20%	40%	4%	20%	40%
cost (M Eur)	1.45	1.45	1.45	-10.125	-10.125	-10.125
benefit (M Eur)	5.1	25.7	51.4	5.1	25.7	51.4
benefit/cost	3.5	17.7	35.4	-0.5	-2.5	-5.1
with 28% modal share (like Dutch in 2019)						
	Alt 2 (improving existing)			Alt 4 (new infra)		
	4%	20%	40%	4%	20%	40%
cost (M Eur)	1.45	1.45	1.45	-10.125	-10.125	-10.125
benefit (M Eur)	22.4	112.0	223.9	22.4	112.0	223.9
benefit/cost	15.4	77.2	154.4	-2.2	-11.1	-22.1

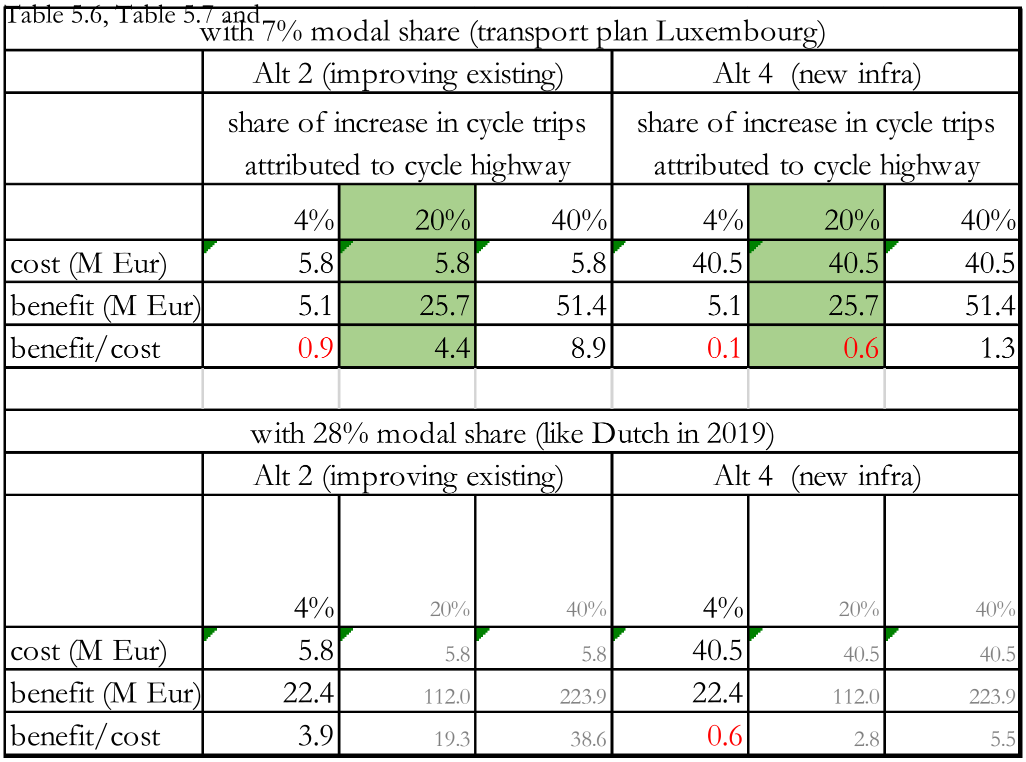
Table 5.9: overview of costs and benefits for different scenario's with halving the costs, 50 000 EU/km for improving the existing and 375 000 EUR/km for the new infra.

Uncertainty, over- or underestimated benefit cost ratio

As our analysis concerns the future, and the future cannot be predicted, our analysis comes with a good part of uncertainty. Part of the uncertainty concerns the costs. That uncertainty has been illustrated in

	with 7% modal share (foreseen in Lux mobility plan)					
	xtra km cycled in 100 000 km			discounted extra km cycle in 100 000km		
	4%	20%	40%	4%	7%	28%
2025	0.2	1.2	2.4	0.2	1.2	2.4
2026	0.5	2.4	4.9	0.5	2.4	4.7
2027	0.7	3.7	7.3	0.7	3.5	6.9
2028	1.0	4.9	9.8	0.9	4.5	9.0
2029	1.2	6.1	12.2	1.1	5.4	10.9
2030	1.5	7.3	14.7	1.3	6.3	12.7
2031	1.7	8.6	17.1	1.4	7.2	14.3
2032	2.0	9.8	19.6	1.6	8.0	15.9
2033	2.2	11.0	22.0	1.7	8.7	17.4
2034	2.4	12.2	24.5	1.9	9.4	18.7
2035	3	13	27	2.0	10.0	20.0
2036	3	13	27	1.9	9.7	19.4
2037	3	13	27	1.9	9.4	18.9
2038	3	13	27	1.8	9.2	18.3
2039	3	13	27	1.8	8.9	17.8
2040	3	13	27	1.7	8.6	17.3
2041	3	13	27	1.7	8.4	16.8
2042	3	13	27	1.6	8.1	16.3
2043	3	13	27	1.6	7.9	15.8
2044	3	13	27	1.5	7.7	15.3
2045	3	13	27	1.5	7.4	14.9
2046	3	13	27	1.4	7.2	14.5
2047	3	13	27	1.4	7.0	14.0
2048	3	13	27	1.4	6.8	13.6
2049	3	13	27	1.3	6.6	13.2
2050	3	13	27	1.3	6.4	12.8
2051	3	13	27	1.2	6.2	12.5
2052	3	13	27	1.2	6.1	12.1
2053	3	13	27	1.2	5.9	11.8
2054	3	13	27	1.1	5.7	11.4
2055	3	13	27	1.1	5.5	11.1
	70	350	699	43	215	431
EUR/km				discounted value of extra cycle km in Million EUR		
1.20				5.2	25.8	51.6

Table 5.6, Table 5.7 and



with 7% modal share (transport plan Luxembourg)						
	Alt 2 (improving existing)			Alt 4 (new infra)		
	share of increase in cycle trips attributed to cycle highway			share of increase in cycle trips attributed to cycle highway		
	4%	🟩 20%	40%	4%	🟩 20%	40%
cost (M Eur)	5.8	🟩 5.8	5.8	40.5	🟩 40.5	40.5
benefit (M Eur)	5.1	🟩 25.7	51.4	5.1	🟩 25.7	51.4
benefit/cost	0.9	🟩 4.4	8.9	0.1	🟩 0.6	1.3
with 28% modal share (like Dutch in 2019)						
	Alt 2 (improving existing)			Alt 4 (new infra)		
	4%	20%	40%	4%	20%	40%
cost (M Eur)	5.8	5.8	5.8	40.5	40.5	40.5
benefit (M Eur)	22.4	112.0	223.9	22.4	112.0	223.9
benefit/cost	3.9	19.3	38.6	0.6	2.8	5.5

Table 5.8.

There are however other uncertainties in the analysis, especially concerning the gains. Below we provide reasons why our benefit over cost ratios could be over or under estimated.

- Reasons for overestimated benefits over cost ratio’s
    - The average distances cycled are shorter than 8 km
    - The cycle share of 7% is not obtained in 2035
    - In the future a part of the cyclists use speed pedelecs which have higher costs
    - The health gains per km are lower with longer average distances cycled
    - The costs for infrastructure building are higher than expected
    - ….
- Reasons for underestimated benefits over cost ratio’s
    - The average distances cycled are longer than 8 km
    - The cycle share of 7% is obtained before 2035 and/or continuous growing after 2035
    - The costs for infrastructure building are lower than expected
    - ….

Conclusion: significantly upgrading the existing infrastructure is a no regret option

We can conclude that significantly upgrading the existing is a no regret option. The intermediate scenario for the alternative 2 upgrade scenario with 7% modal share in 2035 and 20% of cyclists attributable to the cycle highway provides benefits nearly 9 times bigger than the costs.

Even for more pessimistic scenario’s, the benefits remain bigger than the costs.

With a cost of 100 000 EUR/km for the upgrade, and with only 4% of the new cyclists, the cycling modal share needs to reach only 4.2% instead of 7% in 2035 to have benefits that are larger than the costs.

With a cost of 100 000 EUR/km, and with 20% of the increase in cyclists that is attributed to the cycle highway, a 1.5% modal share is sufficient to generate benefits larger than costs.

Building a completely new infrastructure is less straightforward. There is some more uncertainty about positive benefit over cost ratio's. Even if the intermediate scenario still provides benefits that are 30% bigger than the costs with a cost of a 750 000 EUR/km. In the more pessimistic or conservative scenario's where only 4% of cyclists are attributed to the new cycle highway, the costs surpass the benefits. For evaluating the building of the new infrastructure, there is also the fact that part of the cyclists will use other existing infrastructure. Benefits will therefore probably be lower than the figures provided in the table.

6 Policy Recommendations

Thanks to the huge (health) benefits of cycling, investments in cycling projects are most always worthwhile. Investments in cycling can lead to very large savings for the government in terms of lower healthcare costs, reduced pollution and increased productivity. Our case study on the Arlon-Luxembourg corridor shows that even in areas with a limited cycle culture and on routes that require border crossing, investments in cycling infrastructure have a positive return.

We also show that the potential for a modal shift from passenger car use to cycling is huge. The majority of car trips are short distance trips that could be replaced by an (e-)bike trip. The economic gains of such a modal shift are extremely large.

The challenge is to identify the hurdles that people face to ride bicycles and to equip policy makers with adequate tools to overcome these hurdles and stimulate cycling in the most efficient way. In the following sections, we discuss a list of priority measures for policy makers to boost cycling activity.

6.1 Invest in safer, faster and more convenient cycling infrastructure

Improve safety through infrastructure investments

The cost-benefit analysis showed that accident risk and therefore accident costs of cycling are relatively high compared to other modes of passenger transport. In addition, while accident risk for car users decreased significantly over time as a result of investments in car infrastructure, this is not the case for cycling (ETSC, 2020).

The accident costs that are taking into account by the cost-benefit analysis are **objective safety costs**. Objective safety is equal to the actual number or risk of road accidents and injuries. Road users are also confronted with **subjective safety costs**, which are not taken into account in most economic analyses. Subjective safety is the feeling or perception of safety ("How safe do you feel?"). Both objective and subjective safety costs prevent people from enjoying the benefits of cycling. If you talk to people that currently don't cycle, often they say they feel unsafe due to existing infrastructure or traffic conditions.

Authorities can improve objective and subjective safety through investing in cycling infrastructure. A recent survey on urban cycling in Germany shows that **dedicated cycle tracks** provide the highest level of subjective safety, followed by cycling lanes. Cycling on the street is perceived as the most dangerous. Subjective safety of cycling is significantly improved by a **physical separation between cyclists and cars, an increased width of the cycle lane, and a coloured surface** (von Stülpnagel and Binning, 2022). The factors identified to improve subjective safety are similar to those benefitting objective safety.

Note that traffic safety improves most if it is approached in a holistic way. Improving cycling infrastructure is a first and crucial step, but it should be combined with proactive measures and the constant management of the dynamic interaction between vehicles, road infrastructure and road user behaviour. Such a systematic approach towards road safety is prescribed in the **Safe System approach** by the International Transport Forum (ITF, 2016). It is designed around the idea of a

shared responsibility amongst road designers, managers and users to prevent crashes. Therefore, next to the design and development of safe cycling infrastructure, bicycle safety can be further improved by measures such as:

- a revision of the road code, where cyclists receive a more prominent role. Currently, road codes are car-centered.
- security campaigns (e.g. the use of a helmet, bike lightning, raising awareness among other road users,…)

Improve speed and directness through infrastructure investments

Especially for relatively longer distance trips, **travel speed is an essential concern for cyclists**. In the cost-benefit analysis, we showed that on average, bicycles are slower than other passenger transport modes. This leads to high time costs, which can be an important hurdle for people to use a bike. Time costs are especially relevant for commuting and business trips, during which time is valued higher than during leisure trips.

If well-designed, **cycle highways** can increase the cycling speed significantly and thus lower time costs. Average cycle speed on cycle highways increases to 18 km/h for push bikes and 24km/h for e-bikes (Rupprecht Consult, 2016).

A point of attention is that in most countries, speed pedelecs are not allowed to use the bicycle infrastructure, including the cycle highways. In Germany, Luxembourg and the Netherlands, speed pedelecs are considered as electric motorcycles. **Barring speed pedelecs from cycle highways might be a missed opportunity**. The provision of a clear and attractive framework for speed pedelecs combined with the development of high quality infrastructure will increase the average speed of all cyclists. Preventing speed pedelecs to use cycle infrastructure is based on safety concerns. Therefore, we recommend to investigate to what extent speed pedelecs pose a true safety risk on cycle highways (both objective and subjective safety). A potential solution could be to introduce speed limits up to 30km/h, provided that such a speed limit is enforceable.

Cycle highways are adequate infrastructure to connect two cities or to create a long-distance cycling track. In an **urban environment**, the average travel time of cyclists can be reduced in different ways. Examples **are reducing the number of junctions that cyclists need to pass, reducing the time spent at traffic lights, and providing easy-to-access bike parking**.

Improve convenience through infrastructure

To maximally reap the mental benefits from cycling, cycling infrastructure should be designed such that bike riders can enjoy their trip. **Convenient cycling infrastructure** avoids too much altitude differences, separates cyclists from car traffic, and avoids frequent stops caused by obstructions. Cycling infrastructure should be dedicated to cyclists and not be shared with pedestrians, unless in wider areas.

Another way to improve convenience for cycling is to ensure that cycling infrastructure is **well maintained on a regular basis**, including repairs and removing debris and gritting. The Arlon-Luxembourg case study provided an example of how this can be implemented. In Luxembourg, farmers clean greenways and agricultural roads after a passage with agricultural machinery. This way, the paths remain neat and accessible to cyclists.

6.2 Increase the relative advantage of cycling compared to other modes

The results of the cost-benefit analysis in Chapter 4 showed that in most countries, the private costs for using a bicycle is higher than the cost to ride in a passenger car or to use public transportation. The Netherlands is an exception, where the private costs of a passenger car trip are relatively large. Hence, the number of cycling kilometres is the largest in the Netherlands.

To increase the modal share of cycling in passenger transport, public authorities should further **reduce the private costs of cycling**. This can be done by **lowering the total costs of ownership**. Alternatively, the government can **reduce the time and safety costs of cycling**. While the previous section focused on the investment in cycling infrastructure to reduce time and accident costs, in this section we discuss the merits of incentives to reduce private ownership and use costs.

Stimulate bike use, not bike ownership

A first way to reduce the private costs of cycling can be achieved by **lowering the total costs of ownership of a bicycle**. For example, the purchase rebate offered by the government of Luxembourg implies a significant reduction of the upfront cost. However, the downside of a purchase incentive, is that it only stimulates bike ownership, not bike use. This financial incentive risks to cost the government a lot of money, while new bicycles remain unused in people's garages. Therefore, our recommendation is to **stimulate cycling, not bike ownership**.

A very effective incentive to stimulate the use of a bicycle is a **cycling commuting allowance**. Such a commuting allowance is already in place, ranging from € 0.19/km in the Netherlands to € 0.30/km in NRW. Luxembourg currently offers no cycling commuting allowance. Based on the results of our study, we provide several recommendations with respect to the commuting allowance:

First, Luxembourg could consider to **exchange the purchase grant to a cycling commuting allowance**. This will stimulate bike use instead of bike ownership. To achieve a maximum impact, the cycling commuting allowance should be higher (or at least equal to) the commuting allowance that exists for passenger cars, which is currently set at € 0.30/km.

Second, the bicycle commuting allowance should be **available to all workers**. In Belgium, the cycling allowance is currently not generally available, but it is part of the ambitions of the BeCyclist Action Plan (Be Cyclist, 2021). Currently, the grant is sector-specific, which raises equity concerns. **A cycling commuting grant should be generalized and be made available to all employees**. A generally applied cycling commuting allowance requires the agreement of the unions and employers federations in each sectoral commission.

When we compare the amount of the cycling allowance to the potential benefits of cycling, we conclude that there should be sufficient margin to **increase the current level of the cycling allowance**. Currently, the cycling allowances in place range from € 19/km to € 30/km. These amounts correspond to the external benefits from riding a speed pedelec (Table 6.1). The external benefits from riding a push bike or an e-bike are significantly higher. Therefore, **each employee that is convinced to ride a bike to work leads to a net benefit to society**. If this worker previously commuted by car, the net benefits are several time higher because it leads to additional cost savings.

We argue that **the costs of the cycling allowance can be shared between the government and the employer**, as it is currently the case in Belgium. The majority of the benefits resulting for commuting to work consists of health benefits. This means a lower number of sick days and a higher rate of labour productivity, that benefits the employer directly. Other benefits such as lower social security costs, lower congestion costs and fewer emissions are benefits to society that serve the government.

Table 6.1 External benefits of cycling versus cycling allowance

	BE	**LU**	**NL**	**NRW**
Push bike	€ 1.48	€ 1.98	€ 1.45	€ 1.38
e-bike	€ 0.85	€ 1.14	€ 0.84	€ 0.80
Speed pedelec	€ 0.31	€ 0.43	€ 0.32	€ 0.31
Cycling allowance	**€ 0.24**	**€ 0.00**	**€ 0.19**	**€ 0.30**

Another way to stimulate cycling and to foster a modal shift from passenger cars to bicycles is to make car users pay for the societal cost of using their vehicle. Given the high social costs of car use, **a commuting allowance for passenger cars is both economically and socially unjustified**. Instead, the social costs caused by car users could be charged. Because congestion is the main source of the social costs, **a road pricing system** could effectively internalize this cost. However, public acceptance and therefore political support for such a system seems rather low.

6.3 Build and maintain the Arlon-Luxembourg cycle highway

The case study presented Chapter **Error! Reference source not found.** demonstrated the potential for a **cross border cycle highway between Arlon and Luxembourg**. The case study showed that an improvement of the current infrastructure generates huge social benefits. The construction of the Arlon-Luxembourg corridor is a very concrete way to improve safety, speed, directness and convenience for cyclists. It will accommodate commuters as well as leisure seekers.

In addition, the corridor may be an attraction pole for tourists, who's presence will further enhance the economic benefits of the cycle highway. Research show that tourists assign a high value to inter-urban cycle highways. A survey amongst tourists in Dublin shows that tourists are willing to double their cycling time in order to cycle on dedicated cycle track, separated from car traffic (Deenihan and Caufield, 2015).

6.4 Create a cycle-friendly attitude and environment

Respect

Cyclists feel sometimes disrespected by public authorities or other road users. This is especially an issue in regions where cycling is not yet widespread. The feeling of disrespect leads to unnecessary frustrations that can easily be avoided. An Arlon-Luxembourg commuter testified that bus drivers keep a very large distance when passing a cyclist The cyclists feels seen and respected and this behaviour contributes to a feeling of safety. The same cyclists testified that the opposite is often the case in Wallonia (Belgium) where buses drive by cyclists at very short distances, although the legal minimum distance to pass by cyclists have recently been increased to 1.5m on roads within agglomerations. Fortunately, the legal minimum distance for passing a cyclists in Belgium has recently been increased to 1.5 meter on a road where the maximum speed exceeds 50 km/h.

Listen to experienced cyclists

Everyday cyclists have a huge amount of knowledge about the state of the cycling infrastructure. They can point to dangerous sections on the track and suggest potential improvements. They are very often eager to share their knowledge with public authorities. The information provided by the Arlon-based cyclist interviewed in this study serves as an illustration.

Integrate cycle policies in all policy domains

Cycling is more than just a means of transportation. It concerns amongst others mobility, health, happiness and livability. To reap the enormous potential benefits of cycling, it is important to not only integrate cycling in transport and mobility policies, but also in housing, health and urban planning policies. This is a practice followed by the Netherlands, one of the largest cycle countries in the world.

6.5 Develop multimodal bicycle-inclusive mobility plans

Although our study shows that a modal shift from any type of motorized passenger transport to bike rides leads to social gains, it is not feasible nor desirable to replace all car trips or all trips by public transportation by bicycle trips. Most often this is due to the trip length, but also other conditions (e.g. weather conditions, physical inability,…) may make cycling not the preferable mode for transportation. A train ride, for example, typically covers a very long distance.

Still, cycling can play an important role as part of a **multimodal (bicycle-train or bicycle-car) trip** (Tetteroo, 2015; BiTiBi, 2017). When public transportation is used, an additional transport mode is often necessary because public transport is limited to dedicated lines which are not always close to the destination of the trip. Therefore, a further development of bicycle initiatives such as **good bicycle parking and shared bicycles at public transport stops** is important.

6.6 Leave nobody behind, work on the image of cycling

Cycling has the potential to be a very democratic means of transport. Our analysis of the total costs of ownership showed that cycling is the most affordable transport mode. Once purchased, riding a bicycle is free of any charge and maintenance costs are minimal. So the more the bicycle is used, the lower the total cost of ownership. Therefore, cycling can be an important tool to combat mobility poverty. For lower income households that cannot afford car ownership, cycling can provide a mobility solution to access essential services.

Cycling is also especially valuable to older people. The health benefits of cycling are very important in for people above 65-years old. Cycling prevents older people from social isolation and allows them to remain socially active for much longer (Dutch Cycling Vision, 2018; Arup, 2020).

Most cycling plans are evaluated on the number of cyclists and not on who would benefit the most (Arup, 2020). In addition in many countries, cycling is still an affair of the middle class. Therefore, cycling strategies and policies should be designed with **a focus on equity and inclusiveness**. This can be done by **prioritizing cycling infrastructure in less affluent areas and/or areas where public transport services are lower**.

References

- Amsterdam and other dutch public authorities, Together we cycle, 2020 . https://togetherwecycle.eu/
- Arlon Cycling Club, (2022) Available at https://www.arlon.cc/blog?category=Bike%20to%20Work
- Arup (2020). Cycling for everyone. A guide for inclusive cycling in cities and towns.
- Batley et al (2019). New Appraisal values of travel time saving and reliability, Transportation 46: 583-621.
- Be Cyclist (2021). Actieplan ter Promotie van de Fiets van de federale regering, 2021-2024. Available at: https://mobilit.belgium.be/sites/default/files/resources/files/fietsactieplan_becyclist_2021-24_nl.pdf
- Beuckers J. et all (2015). Health impact model for modal shift from car use to cycling or walking in Flanders: application to two bicycle highways, Journal of Transport & Health 2, sept 2015, 549-562.
- BiTiBi (2016), BiTiBi Evaluation report summary (EU Steer project)
- BiTiBi (2017), BiTiBi Final report (EU Steer project)
- Bouwen, L., Dons, E. & Schoeters, A. (2022). De impact van fietsen op gezondheid, klimaat en economie in België Literatuuronderzoek en kostenbatenanalyse van een toename van het fietsgebruik in België, Brussel: Vias institute
- CBS (2022). Hoeveel fietsen inwonders van Nederland, Available at: https://www.cbs.nl/nl-nl/visualisaties/verkeer-en-vervoer/personen/fietsen
- CBS (2022) Gemiddelde afgelegde afstand per verplaatsing Available at: https://www.cbs.nl/nl-nl/longread/rapportages/2021/onderweg-in-nederland--odin---2020-plausibiliteitsrapportage/5-gemiddelde-afgelegde-afstand-per-verplaatsing
- Cairns S.et al(2017). Electrically-assisted bikes: Potential impacts no travel behaviour. Transporttation research Part A: Policy and Practice, vol 103, sept 2017, 327-342.
- Castro A. et al (2019). Physical activity of electric bicycle users compared to conventional bicycle users and non-cyclists: Insights based on health and transport data from an online survey in seven European cities, Transportation Research Interdisciplinary Perspectives 1, 100017.
- Crow (2013). Feiten over de elektrische fiets. Fietsberaad publicatie 24
- Daubresse, A., Hoornaert, A., Laine, B. (2022). Vooruitzichten van de transportvraag in België tegen 2040, Federal Planning Bureau.
- Decisio (2014). Maatschappelijke Waarde en Investeringsagenda Fietsen. Verantwoordingsrapportage. In opdracht van Ministerie van Infrastructuur en Milieu.
- Decisio (2017). Bruto Utrechts Fietsproduct. Wat levert een toename van fietsgebruik in de stad op? https://decisio.nl/wp-content/uploads/2017_BUF_rapportage.pdf
- Decisio (2021). Schatting monetaire waarde gezondheidseffecten van bewegen door werknemers. Fietsersbond en Wandelnet.
- Deenihan, G. and Caufield, B. (2015). Do tourists value different levels of cycling infrastructure?, Tourism Management 45, pp. 92-101.
- De Geus, B., Hendriksen, I. (2015) Cycling for Transport, Physical Activity and Health: What about Pedelecs? Cycl.Futures Res. Pract. 28, 17–31.
- Delhaye, E., De Ceuster, G., Vanhove, F., Maerivoet, S. (2017). Internalisering van externe kosten van transport in Vlaanderen: actualisering 2016. Vlaamse Milieumaatschappij. https://www.tmleuven.be/nl/project/miraexternekostenupdate
- De Smedt et al. (2011). A cost-effectiveness study of the community-based intervention “10.000 Steps Ghent”. Public Health Nutrition.

- ECF. (2021). The costs of cycling infrastructure.
- ECF (2018). The benefits of cycling. Unlocking their potential for Europe. European Cycling Federation.
- Ecorys (2017). De sociaal-economische waarde van sport en bewegen.
- Epstein, D. (2010). L'évolution de la vitesse de déplacement domicile-travail au Luxembourg de 1960 à nos jours. CEPS/INSTEAD, Luxembourg et Université de Strasbourg, France.
- ETSC (2020). How safe is walking and cycling in Europe ? PIN Flash Report 38. Available at : https://etsc.eu/wp-content/uploads/PIN-Flash-38_FINAL.pdf
- European Commission, Directorate-General for Mobility and Transport, Monden, R., El Beyrouty, K., Gatto, M., et al. (2019). Overview of transport infrastructure expenditures and costs, Publications Office, 2019, https://data.europa.eu/doi/10.2832/853267
- European Commission, Directorate-General for Mobility and Transport, Essen, H., Fiorello, D., El Beyrouty, K. (2020). Handbook on the external costs of transport : version 2019 – 1.1, Publications Office. https://data.europa.eu/doi/10.2832/51388
- European Commission, Directorate-General for Mobility and Transport, Cycle highways, Available at: https://transport.ec.europa.eu/transport-themes/clean-transport-urban-transport/cycling/guidance-cycling-projects-eu/cycling-measures/13-cycle-highways_en
- Fietsberaad (2019), Aantal speedpedelecs groeit sterk … Available at https://fietsberaad.be/nieuws/aantal-speedpedelecs-groeit-sterk/
- Fietsberaad (2020). Het profiel van de gebruiker van de speedpedelec. Available at: https://fietsberaad.be/praktijk/het-profiel-van-de-gebruiker-van-de-speedpedelec/#:~:text=Waarom%20een%20speedpedelec%3F,ze%20leggen%20gemiddeld%2025km%20af.
- FOD Mobiliteit en Vervoer (2019). Enquête over de mobiliteit van de Belgen. https://mobilit.belgium.be/nl/mobiliteit/mobiliteit_cijfers/enquetes_over_de_mobiliteit_van_de_belgen/monitor
- FOD Mobiliteit en Vervoer (2019). Federale diagnostiek woon-werkverkeer 2017-2018. https://mobilit.belgium.be/sites/default/files/resources/files/final_report_wwv_2017-2018_nl.pdf
- Foguenne Paul, interview with Mr Foguenne on 31-08-2022
- Follmer, R. and Gruschwitz, D. (2019). Mobility in Germany – short report. Edition 4.0 of the study by infas, DLR, IVT and infas 360 on behalf of the Federal Ministry of Transport and Digital Infrastructure (BMVI) (FE no. 70.904/15). Bonn, Berlin. www.mobilitaet-in-deutschland.de
- Fyhri, A., Sundfør, H., Christian Weber, C. (2016). Effect of subvention program for e-bikes in Oslo on bicycle use, transport distribution and CO_2 emissions, TØI Report 1498/2016.
- Hans S. et al. (2017). Effects of upgrading to cycle highways – An analysis of demand induction, use of patterns and satisfaction before and after, Journal of Transport Geography 64 (2017) 203-210.
- Hendriksen, I.J.M., Simons, M., Galindo Garre, F. , Hildebrandt, V.H. (2010). The association between commuter cycling and sickness absence, Prev Med. 2010 Aug, 51(2), 132-5.
- Hoornaert, B., Van Steenwegen, A. (2019). De kosten van verkeerscongestie in België. Een verkenning aan de hand van het PLANT-model. Federaal Planbureau
- ITF (2022). Streets That Fit: Re-allocating Space for Better Cities, International Transport Forum Policy Papers, No. 100, OECD Publishing, Paris.
- ITF (2016). Zero Road Deaths and Serious Injuries. Leading a Paradigm Shift to a Safe System, OECD Publishing, Paris.

- Kortenberg (2019), Speedpedelecs zijn toegelaten op de fietssnelweg F3 Available at: https://www.kortenberg.be/speed-pedelecs-zijn-toegelaten-op-de-fietssnelweg-f3
- L'essentiel, 19-12-2017. A la frontière, deux tiers travaillent au Grand-Duché https://www.lessentiel.lu/fr/story/a-la-frontiere-deux-tiers-travaillent-au-grand-duche-904895543814
- Litman, T. (2022). Evaluating Active Transport Benefits and Costs. Guide to valuing walking and cycling improvements and encouragement programs. Victoria Transport Policy Institute.
- Litman, T. (2009), Transportation Cost and Benefit Analysis Guidebook, VTPI (www.vtpi.org/tca)
- Macedo et all. 2022. Cycle highway effects: Assessing Modal Shift to Cycling in the Netherlands
- Ministère de la Mobilité et des Travaux publics luxembourgeois. 2022. Plan National de Mobilité, 2035.
- Ministère de l'Environnement, du Climat et du Développement durable. (2022). Clever Fueren. Poursuite et réorientation des aides financières pour la mobilité électrique et la mobilité active.
- Ministère des travaux publics. 2014. Réseau cyclable, PC12 et 13. https://travaux.public.lu/fr/reseau-cyclable/itineraires-nationaux/pc12.html https://travaux.public.lu/fr/reseau-cyclable/itineraires-nationaux/pc13.html
- Ministère du Développement durable et des Infrastructures (2017). Enquête Luxmobil 2017. Available at: https://transports.public.lu/fr/publications/situation-actuelle/enquete-luxmobil-2017.html
- Mobiel21 (2014). Het e-fietspotentieel. Resultaten online-bevraging e-fietspendelaars, 7 juli 2014.
- Modu 2.0 (2020). Stratégie pour une mobilité durable. Élaborée par Département des Transports, Direction de la Planification de la Mobilité.
- Monitor (2019). Nationaal onderzoek inzake mobiliteit en verkeersveiligheid. FOD Mobiliteit en Vervoer. Available at: https://mobilit.belgium.be/sites/default/files/partie_mobilite_nl-final_1.pdf
- Office for Cycle Superhighways (2019). Cycle Superhighway Bicycle Account, Key figures from the cycle superhighways in the Capital Region of Denmark.
- Petzoldt, T., Schleinitz, K., Heilmann, S., Gehlert, T. (2017). Traffic conflicts and their contextual factors when riding conventional vs. electric bicycles, Transportation Research Part F: Traffic Psychology and Behaviour, Volume 46, Part B, p. 477-490.
- Racca, D., Dhanju. A. (2006). Property Value/Desirability Effects of Bike Paths Adjacent to Residential Areas. University of Delaware, Delaware Center for Transportation Working Paper 188.
- REAL. (2021). Tableau de bord socio-économique de la province du Luxembourg
- Rupprecht Consult (2016). FLOW: Cycling Measures – A cause of congestion or a solution to it?
- Schepers, P., Wijnen, W. (2015). Verkenning gezondheid en tweewielerbeleid. Rijkswaterstaat. Ministerie van Infrastructuur en Milieu. Available at: https://fietsberaad.nl/Kennisbank/Verkenning-gezondheid-en-tweewielerbeleid
- Schroten, A., van Essen, H.P., Aarnink, S.J., Verhoef, E., Knockaert, J. (2014). Externe en infrastructuurkosten van verkeer. Een overzicht voor Nederland in 2010. CE Delft, 2014.
- Steinbuch, M. (2014). Elektrisch rijden: voor ZZP en BV aanschaf 2016-2020. Available at: https://maartensteinbuch.com/2014/11/04/elektrisch-rijden-voor-zzp-en-bv-aanschaf-2016/
- Tetteroo, E. (2015). Urban Cycling = ~~HOT~~ HOD. A Study of the Relationship Between Urban Planning and the Hybrid Bicycle-Train System in Dutch Planning Practice. Erasmus University Rotterdam.
- TNO (2010). Fietsen is groen, gezond en voordelig – 10 argumenten om (meer) te fietsen.
- Van den Steen, N., B. Herteleer, J. Cappelle, L.Vanhaverbeke,. (2019). Motivations and Barriers for Using Speed Pedelecs for Daily Commuting. World Electric Vehicle Journal, 10. 87.

- van der Salm, M.M. (2020). De speed pedelec: wie zijn de gebruikers? Een multi-dimensionale segmentatie van speed pedelec-gebruikers in Nederland. Universiteit Utrecht.
- van Wee, B., Börjesson M. (2015). How to make CBA more suitable for evaluating cycling policies, Transport Policy 44, 117-124.
- Van Zeebroeck B. (2014) Impact en Potentieel van fietsgebruik voor de economie en de werkgelegenheid in het Brussels Gewest.
- Van Zeebroeck B., Baert, W., Caers, I. and Marchal, R. (2018). Fietsbeleid brengt op. Studie voor Fietsberaad Vlaanderen, Available at: https://www.tmleuven.be/nl/project/kostenbatenfiets
- VeiligheidNL (2022). Vervolgonderzoek naar fietsongevallen 2020-2021. Available at: https://www.veiligheid.nl/kennisaanbod/infographic/infographic-vervolgonderzoek-naar-fietsongevallen-2020-2021
- Verstappen, E.M.J., Vy, D.T., Janzing, H.M. et al. (2021). Bicycle-related injuries in the emergency department: a comparison between E-bikes and conventional bicycles: a prospective observational study. Eur J Trauma Emerg Surg 47, 1853–1860.
- Vlaams Brabant (2018), Fietssnelweg Leuven-Brussel in beeld
- von Stülpnagel, R., Binnig, N. (2022). How safe do you feel? – A large-scale survey concerning the subjective safety associated with different kinds of cycling lanes, Accident Analysis & Prevention, 167, 106577.
- VRT (2015), Vlamingen fietsen gemiddeld vrij ver. Available at https://www.vrt.be/vrtnws/nl/2015/12/09/vlamingen_fietsengemiddeldvrijver-1-2518894/