Speed differences of conventional and pedal assisted bicycles in Austria

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ABSTRACT

The increasing number of pedal assisted bicycles on roads and cycling facilities lead to new safety challenges. One main concern is the difference between the actual driving speeds of bicycles with and without electric support. A substantial speed difference between road users in a mixed traffic environment can lead to an increased number of conflicts, near accidents and actual accidents and can also reduce the subjective level of safety.

The aim of this study funded by the Austrian Road Safety Board (KFV) therefore is to investigate the speed differences between conventional bicycles and bicycles with electric support as well as to survey the users on their perception of safety conditions in real traffic.

Two main research questions shall be answered:

[1] Does a person choose a different speed level on different bikes or do people stay in their personal comfortable speed zone?

[2] Does the mean speed of speed pedelecs and conventional bikes differ significantly on the same infrastructure?

A sample of 101 people is riding each of three bicycles (conventional bicycle, pedelec and speed pedelec) on the same circular course in a real traffic environment. Relevant indicators like mean and maximum velocity or acceleration are measured using a GPS sports tracker. In addition, participants will be asked through a standardised questionnaire about their experiences and their subjective level of safety during the test ride.

The analysed data showed [1] that a person does not have a personal comfortable speed zone but the riding speed depends on the bike someone is riding and [2] that the mean riding speed of conventional bikes and speed pedelecs in opposing riding styles differ.

Finally, recommendations for legislation to traffic authorities on what types of vehicle should be allowed on what types of facilities can be derived from the results of this study.

Keywords: speed pedelec, pedelec, speed difference, cycling infrastructure.

1 INTRODUCTION

The fight against climate change and the limited amount of fossil fuels lead to the development of new engine systems running on renewable energy sources. Therefore, electric powered vehicles are one of the big trends of our time. Besides electric powered personal and commercial cars also “green” vehicles like bicycles or scooters with electric support are becoming more and more popular.

In 2019, 439,000 bicycles were sold in Austria which is a decrease of 4% compared to 2018. In total, 170,000 e-bikes were sold which is a market share of 39% in 2019 compared to 33% in 2018. The market share of e-bikes is steadily increasing the last few years throughout Europe (VSSÖ, 2019). This development can also be traced back to measures by the authorities such as the “Umsetzungsplan Elektromobilität” (action plan e-mobility) (BMLFUW et al., 2012).

Unfortunately, the statistic does not differentiate e-bikes without pedalling support[1] and bicycles with electric pedalling support, namely pedelecs or speed pedelecs. Therefore, it is impossible to say how many bikes of any given type are exactly in use and on the roads.

In Switzerland e-bikes have got a market share in new bought bikes of 36.6% and in Germany they have got a market share of 31.5%. Belgium has got the highest market share of e-bikes in the European Union with 51% (VSSÖ, 2019) of new bought bikes.

Reasons for the increased popularity of e-bikes are more comfort, less effort and higher speeds. The higher speed enables you to reach a certain destination faster or cover a larger range. Through these advantages e-bikes have got the potential to be an alternative to using a car. Especially when car rides are replaced by e-bike rides, there is a significant positive effect on the environment (Wachotsch et al., 2014). In addition to that, several studies suggest that riding a bike with pedalling assistance has a positive effect on a person's health similar to riding a conventional bicycle (Jones et al., 2016; Sundfør and Fyhri, 2017).

Naturally, pedelecs and speed pedelecs have disadvantages as well. The higher speeds result in new challenges in terms of traffic safety. One main concern is the difference between the actual driving speeds of bicycles with and without electric support. A substantial speed difference between different road users in a mixed traffic environment can lead to an increased number of conflicts, near accidents and actual accidents and can also reduce their subjective level of safety.

In 2017, 32 cyclists were killed in Austria, 7 out of them were riding an e-bike. In 2018, 41 cyclists were killed and already 17 out of them were riding an e-bikes. In 2019, 33 cyclists were killed and 11 out of them were riding an e-bike.

[1] Vehicles that appear like a moped and often don't even have foot pedals. Dependent on their rated power they are by law bicycles or mopeds. Due to the very different style of riding as well as their different optical appearance compared to bicycles with or without pedalling assistance, these vehicles are excluded from the present study.

Driving an e-bike is quite different from driving a conventional bicycle. It is likely to underestimate your own speed which could lead to dangerous situations. In addition to that, e-bikes are especially interesting for older people. Three quarters of all e-bikers killed in Austria in 2018 as well as in 2019 were older than 65 years, the average age was around 71 years in 2018 and 61 years in 2019 with a median of 75 years in 2019 (APA-DeFacto, 2019; Statistik Austria, UDM, 2020).

1.1 Aim of the study

The aim of the present study is to investigate the speed differences between conventional bicycles and bicycles with electric support as well as to survey the users on their perception of safety conditions in real traffic. Looking at the collected data we get a good idea of the different riding speed of the participants with the three types of bicycles. The assumption is that higher speed in general and larger speed differences between road users increase accident risks and lead to an unsafe mixed traffic environment. But this is only an assumption, so it cannot scientifically be concluded within this study that larger differences cause more conflicts or even accidents. Schleinitz et al. discussed similar postulates in their paper and stated that "*the question of whether their overall higher speed makes e-bike riders more accident prone remains yet to be answered"* as well as *"the actual road safety impact of e-bikes and their potential to reach higher speeds can, at this stage, be only predicted in very broad terms."* (Schleinitz et al., 2017).

In this paper, we therefore focus on two research questions:

[1] Does a person choose a different speed level on different bikes or do people stay in their personal comfortable speed zone no matter which bike they are riding?

[2] Does the mean speed of speed pedelecs and conventional bikes differ significantly when riding in different styles on the same infrastructure?

The discussion will mainly focus on the speed in various scenarios and their interpretation together with the results of the questionnaire.

2 METHODOLOGY

The study can be divided into two research parts - a quantitative and a qualitative one. Within the quantitative part the actual speed difference between three different types of bicycles shall be determined through test rides of a sample group of 101 people. In the qualitative part the sample will be asked several questions on their experiences and opinions on the test rides through a standardised questionnaire. In the following, the two parts of the study will be described in detail.

2.1 Quantitative Part - the test rides

In the quantitative part of the study a sample of 101[2] people from different age groups are riding three different types of bicycles on a selected circular course with varying topography in a real traffic environment. The measurement of the relevant indicators like mean and maximum velocity or acceleration is achieved using a GPS sports tracker. The participants are asked to simulate different ways of cycling like relaxed or sporty on different sections of the test track.

2.1.1 Sample

In the original design of the study the sample should at least consist of 100 people and be equally distributed in different age groups and sex. The testing was advertised through social media, flyers and mailing lists and more than 130 people applied for a test ride. Due to bad weather conditions some testing days had to be cancelled and some of the participants cancelled the test

[2] 101 people participated in the questionnaire and in the test rides with the conventional bike and the pedelec. 2 participants couldn't take part in the test rides with the speedpedelec.

rides for private reasons, resulting in a sample of 101 people. Every person in the sample eceived a voucher for a sports store worth € 30.- as an allowance.

Figure 1 shows the distribution of age and sex in the sample. There were 31 women and 70 men. 12 people were adolescents between the age of 16 and 24 (in Austria, you have to be at least 16 to drive a moped - or a speed pedelec) and nearly one quarter of the sample were young adults between the age of 25 and 30. With 46% most of the participants were adults aged between 31 and 60. 19 people were 61 years old or older.

In Austria, 10% of the population are adolescents, 8.2% aged between 25 and 30, 42.8% are adults between 31 and 60 and 23.6% are older than 60 (Statistik Austria, 2020). Apart from the group of young adults, the sample's age distribution resembles Austria's age distribution quite well. Unfortunately, this cannot be said about the distribution of sex. While the population in Austria consists of nearly as many men as women (49.2% male to 50.8% female) there are only 31/101 women in the sample.

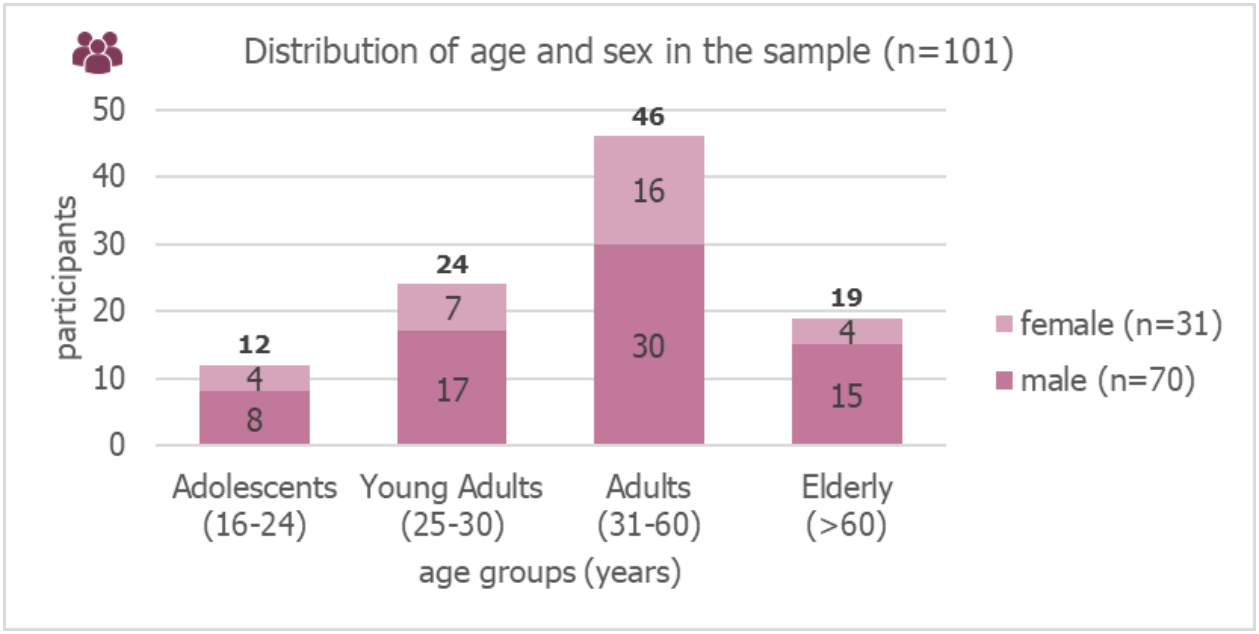


Figure 1. Distribution of age and sex in the sample.

2.1.2 Test track

A test track combining varying topography with uphill and downhill sections on public streets with low traffic and without obligatory bike paths could be found in Meidling, the 12th district of Vienna. Along the Oswaldgasse and the Graffitistraße, a 1.5 kilometre long route was selected that was split into seven sections. These seven sections will be used to analyse the test rides of the participants.

- Section 1: ascent
- Section 2: right turn
- Section 3: plain, participants were asked to drive sporty, at a good pace
- Section 4: turning point, U-turn
- Section 5: plain, participants were asked to drive in a relaxed, unstressed way
- Section 6: left turn
- Section 7: descent

The ascent and descent sections had a mean slope of approximately 3%.

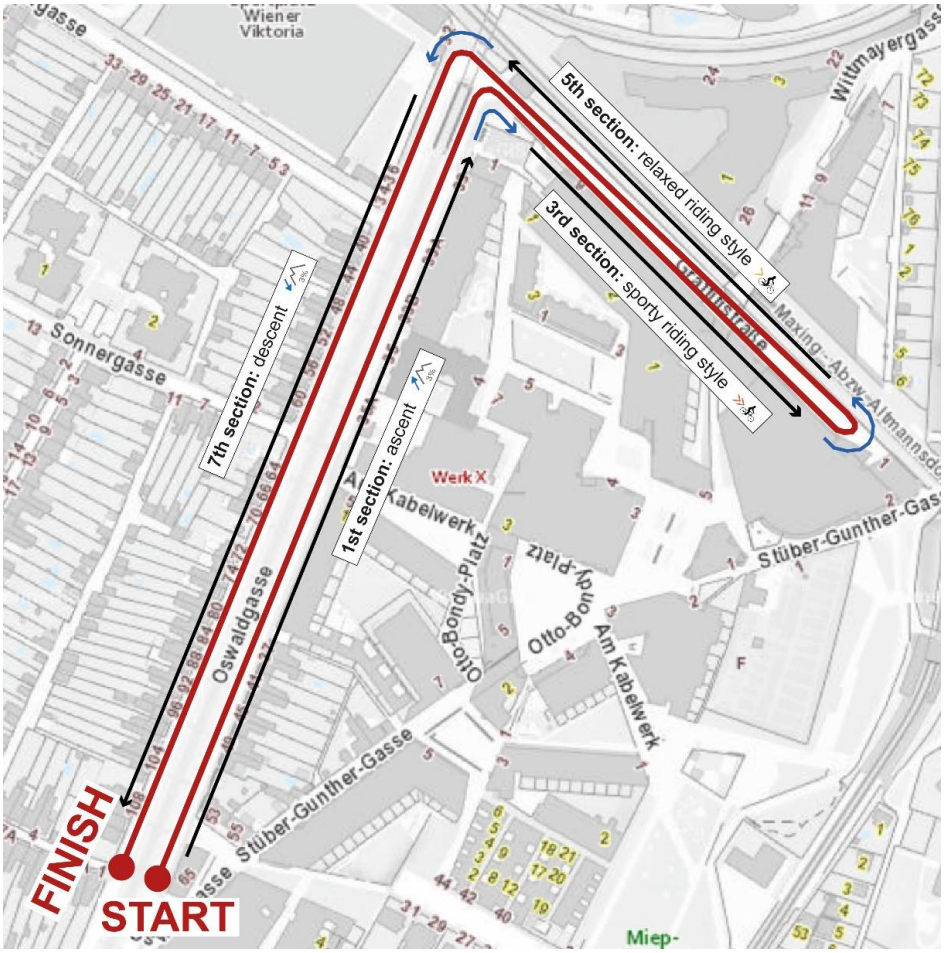


Figure 2. Overview of the test track.

2.1.3 Measurement device

To track the participants performances during the test rides a Polar M430 GPS running watch was used. Amongst others the following data could be collected:

- GPS-track of the route,
- instantaneous velocity (measured every second),
- mean speed for each test ride,
- maximum speed for each test ride.

To ensure reliable and comparable results, the test rides were supervised by a researcher.

2.1.4 Bicycles

The participants were asked to ride each of three different types of bicycles during the test rides - a conventional bike without any kind of pedalling support, a pedelec and a speed pedelec. The order of the bikes was chosen randomly. The following 5 bikes were provided by a sports shop exclusively for this study:

- **Conventional bikes:**

  The two bikes used in this study were a
  - Miles City 3 and a
  - Miles Legend TR 2.

- **Pedelecs:**

  A pedelec, or pedal electric cycle, is a bicycle with pedalling assistance. It has a maximal rated power of 250W and provides pedalling assistance to the driver up to 25 kilometres per hour. Higher speeds can only be reached with muscular strength. The two pedelecs were a
  - KTM Macina Sport 9 CX5 and a
  - KTM Macina Tour 10 P5.

- **Speed pedelecs:**

  A speed pedelec[3], or speed pedal electric cycle, is by law not a bicycle but actually a moped in Austria. It provides pedalling assistance up to 45kph and has a maximal rated power of 600W. Due to its legal status as a moped a valid driving licence is necessary to ride this vehicle. Further, it needs type approval and registration, third-party insurance and periodic technical inspection. It's also mandatory to wear a certified

[3] The term s-pedelec is used for abbreviation in figures or tables.

motorcycle helmet and its use in cycle paths is forbidden. The speed pedelec used within this study was a

- Kalkhoff Integrale Speed i10.

2.2 Qualitative Part - The questionnaire

In addition to the quantitative part, the results of the qualitative part shall provide insights on how the participants feel during the test rides and on their personal opinions of the different types of bicycles. The results of this part on the one hand shall help to better understand the results of the quantitative part of the study and on the other hand shall add to results of the study in general.

Besides the usual demographic questions, the questionnaire covers topics like personal experience with biking in general and with the three different bicycles in specific, the opinion of the participants on and their experience with the different bikes as well as their subjective level of safety during the test rides.

The whole questionnaire used for this study can be found in the appendix.

3 RESULTS

3.1 Descriptive results of the test rides

This first part of the results shall provide an overview of the speed levels and differences of the three different types of bicycles. The presented results are only descriptive and shall give the reader an idea of the measured data. For each test ride and for each section of the test track the mean speed and the maximum speed for each participant was calculated. For further comparisons, the median of the mean speeds and the maximum speeds was calculated, respectively.

To get an idea of the speed level in this study, Figure 3 shows the median speed of different groups in the sample. The overall median speed of all test rides with every type of bicycle is 20.9kph. Male drivers seem to go a little faster than female drivers in this sample, but the difference of 0.8kph can be neglected for the aim of the study.

Figure 3 also indicates that the participants tend to drive at higher speeds with a speed pedelec than with a pedelec and a conventional bicycle on average and that the differences of the median speed between a pedelec and a conventional bike is even slightly bigger than between a pedelec and a speed pedelec.

A comparison between the median speed of the different age groups also seems to show what one would expect. Elderly drivers went at the lowest speed on average while the group of adolescents tend to travel the fastest over all three different types of bicycles.

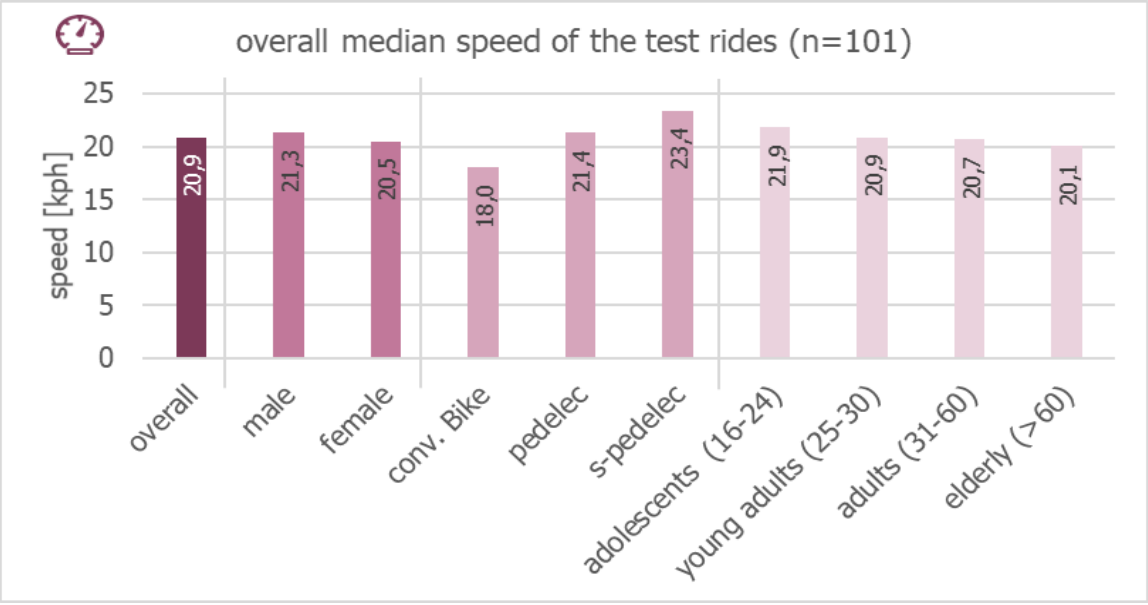


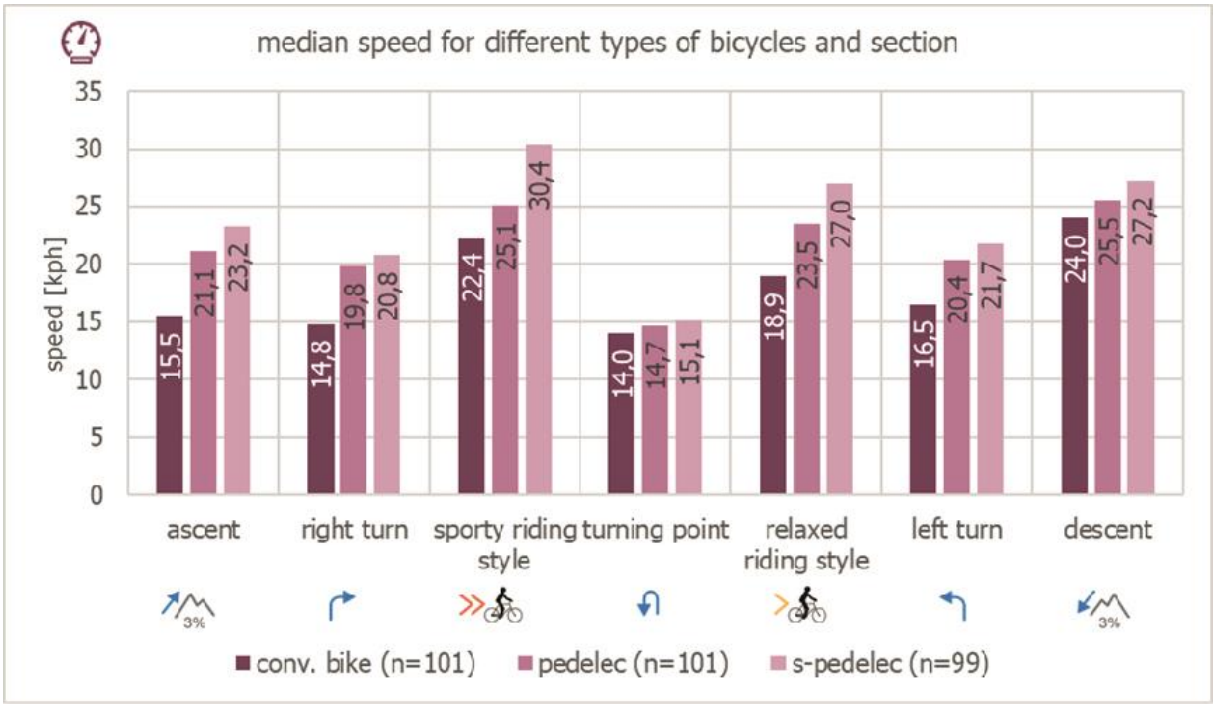
Figure 3. Median speed overall and of different groups.

As described in “Methodology”, the test track was split into 7 sections with varying topography and different cycling styles. Figure 4 shows the median speed for the three different types of bicycles in the 7 sections of the test track.

As one would expect, the participants tend to drive slower in turns than on straight sections. The speed of the three types of bikes is nearly identical at the turning point while in the right and left turn there seems to be a difference, mostly between the conventional bicycle and the ones with electric assisted pedalling. The participants tend to ride approximately 5kph slower on average with conventional bikes. Besides the turning point, the smallest difference between the median speed was measured in the descending section, where the difference of the median speed of the three types of bicycles is at most 3.2kph. The biggest differences were measured in the ascending and plain sections. People tend to ride a speed pedelec more than 8kph faster than a conventional bike on average when they were asked to ride in a relaxed way. The results for the section riding in a sporty style are very similar.

Another noticeable fact is that in the straight sections the median speed of the pedelecs is approximately 25kph, which is the speed limit for pedalling support. Only in the ascending section the median speed is slightly lower. For the speed pedelec, this is not the case. A speed pedelec provides pedalling support up to 45kph, the median speed in all section is far below this value. With 30.4kph there is a gap of almost 15kph between the largest median speed of a speed pedelec (sporty style riding) and the speed limit for pedalling assistence.

Looking at all sections and bicycle types, the participants reached the largest median speed riding a speed pedelec in a sporty way.



222

223 **Figure 4.** Median speed for different types of bicycles and all sections.

224 Looking at the median of the maximum speed in Figure 5, the largest value is still reached with
225 a speed pedelec riding in a sporty way. The overall maximum speed a participant reached with
226 any of the bicycles was nearly 47kph with a speed pedelec riding in a sporty way. That is slightly
227 faster than riding in the descending section and even 2kph faster than the speed limit of the
228 pedalling assistence.

229 Another interesting fact may be that the participants managed to surpass the speed limit for the
230 pedalling assistance for the pedelec when riding in a sporty way. The median of the maximum
231 speed is 27.1kph. Except with the speed pedelecs, the participants on average rode at faster
232 maximum speeds in the descending section than in the sporty riding section. In the descending
233 section the fastest maximum speed with a pedelec was reached with 40.3kph.

234 Comparing the maximum speed the participants, one will notice that in the sporty riding section
235 as well as in the relaxed riding section maximum speed of the conventional bikes was larger than
236 maximum speed of the pedelecs, even though the median of the maximum speed is lower for

conventional bikes. For the sporty riding section, the maximum speeds measured are 41.2kph for the conventional bike and 37.2kph for the pedelec which is a difference of 4kph. For the relaxed riding section, the difference is even bigger with 6.2 kph measured at maximum speeds of 36.8kph (conv. bicycle) and 30.6kph (pedelec).

It can also be observed that the maximum speeds participants reached with any of the three different bicycles tend to be larger that the median of the maximum speed of the "more powerful" bike in any section.

Due to technical challenges during the measurement and therefore questionable validity, the sections right turn, turning point and left turn are excluded from these considerations.

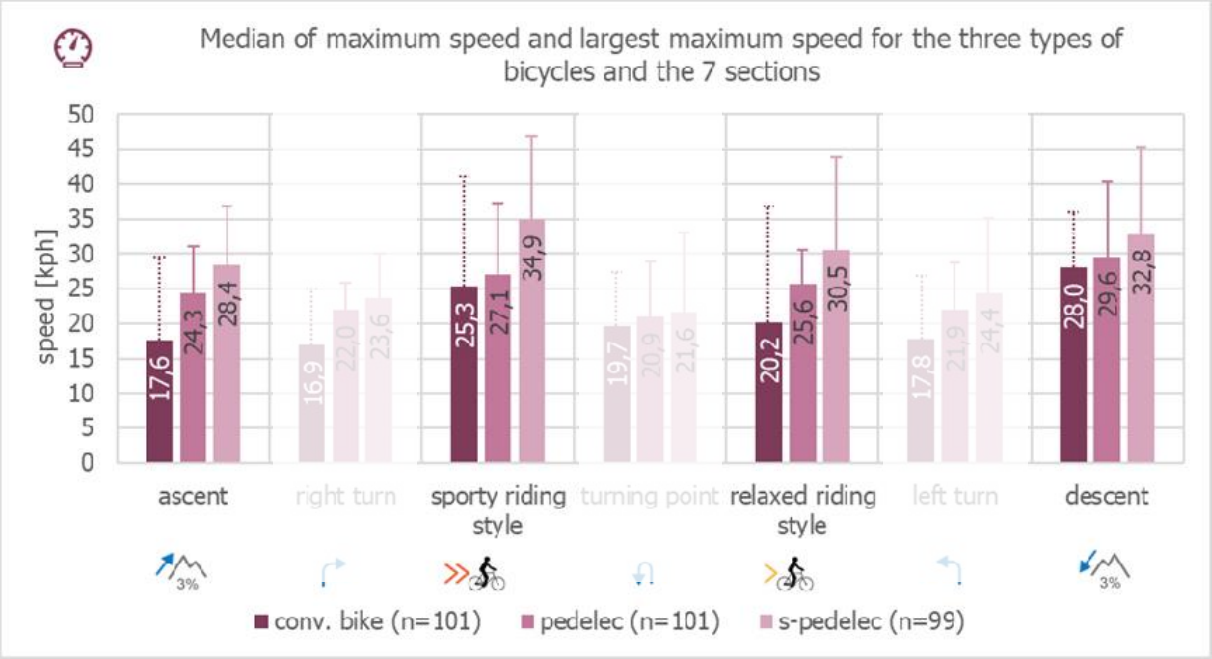


Figure 5. Median of maximum speed (bar) and largest maximum speed (whisker) for the three types of bicycles and the 7 sections.

3.2 Statistical testing

After describing the data and having a feeling for the average speed and the maximum speed the participants reached with each of the three different bicycles and also for the speed

252 differences between the bikes, we will now have a look on some specifically traffic safety
253 relevant comparisons.

254 The first question we address is whether a person chooses a different speed level on different
255 bikes or if people stay in their personal comfortable speed zone no matter which bike they are
256 riding. Therefore, we test whether the speed differences are significantly greater than zero. It
257 seems obvious that people ride at higher speed when using a more powerful vehicle or, in this
258 case, a vehicle with electric support. It is possible though that people have some kind of personal
259 comfortable speed zone which they do not leave no matter how powerful the vehicle is. We
260 compare the mean[4] speed differences between the participants riding the three bicycles in two
261 different riding styles (SS, SR, PS, PR, BS, BR[5]), ending up comparing 15 different pairs (e.g. bike
262 driven in a sporty way and speed pedelec driven in a relaxed way) as seen in Figure 6. In this
263 comparison a pair of a bike with greater level of assistance (speed pedelec>pedelec>conv. bike)
264 and presumably faster riding style (sporty>relaxed) is always compared to a pair with minor
265 components, never the other way around. The level of assistance of the bike weighs more than
266 the riding style. (e.g. SS-PS, PR-BS). We used a paired t-test to test whether the mean speed
267 differences are significantly greater than zero or not using a level of significance of α=0.05. Table
268 1 shows the results of the tests together with the Holm adjusted p-values. We see that all
269 differences are significantly greater than zero (all adjusted p-values are less than 0.05). The
270 smallest test statistic belongs to the the pair pedelec relaxed - conventional bike sporty
271 indicating that the mean speed difference between the bikes in the certain ways of riding is quite
272 small.

[4] In the descriptive part the median is used to describe the different speed levels because of its robustness against outliers. In this second, statistical part the arithmetic mean is used for comparison because of its analytically more approaching properties.

[5] S = speed pedelec, P = pedelec, B = conventional bike;
S = sporty, R = relaxed

273 Table 1. Results of paired t-tests with Holm correction of 15 pairs of all three bicycles and

274 different riding styles.

Pair	Mean of mean speed differences (kph)	Test statistic	Df	P-value
speed pedelec sporty - speed pedelec relaxed	2.72	4.87	98	2.15×10^{-6}
speed pedelec sporty - pedelec sporty	4.42	11.4	98	5.77×10^{-20}
speed pedelec sporty - pedelec relaxed	6.62	12.08	98	2.07×10^{-21}
speed pedelec sporty - conv. bike sporty	7.31	15.78	98	5.75×10^{-29}
speed pedelec sporty - conv. bike relaxed	10.74	19.4	98	1.26×10^{-35}
speed pedelec relaxed - pedelec sporty	1.7	3.57	98	0.000278
speed pedelec relaxed - pedelec relaxed	3.89	9.33	98	1.69×10^{-15}
speed pedelec relaxed - conv. bike sporty	4.58	8.05	98	10^{-12}
speed pedelec relaxed - conv. bike relaxed	8.02	17.87	98	6.64×10^{-33}
pedelec sporty - pedelec relaxed	2.12	6.52	100	1.47×10^{-9}
pedelec sporty - conv. bike sporty	2.96	8.92	100	1.14×10^{-14}
pedelec sporty - conv. bike relaxed	6.34	16.32	100	3.02×10^{-30}
pedelec relaxed - conv. bike sporty	0.84	1.69	100	0.047
pedelec relaxed - conv. bike relaxed	4.22	10.6	100	2.44×10^{-18}
conv. bike sporty - conv. bike relaxed	3.38	9.72	100	2.02×10^{-16}

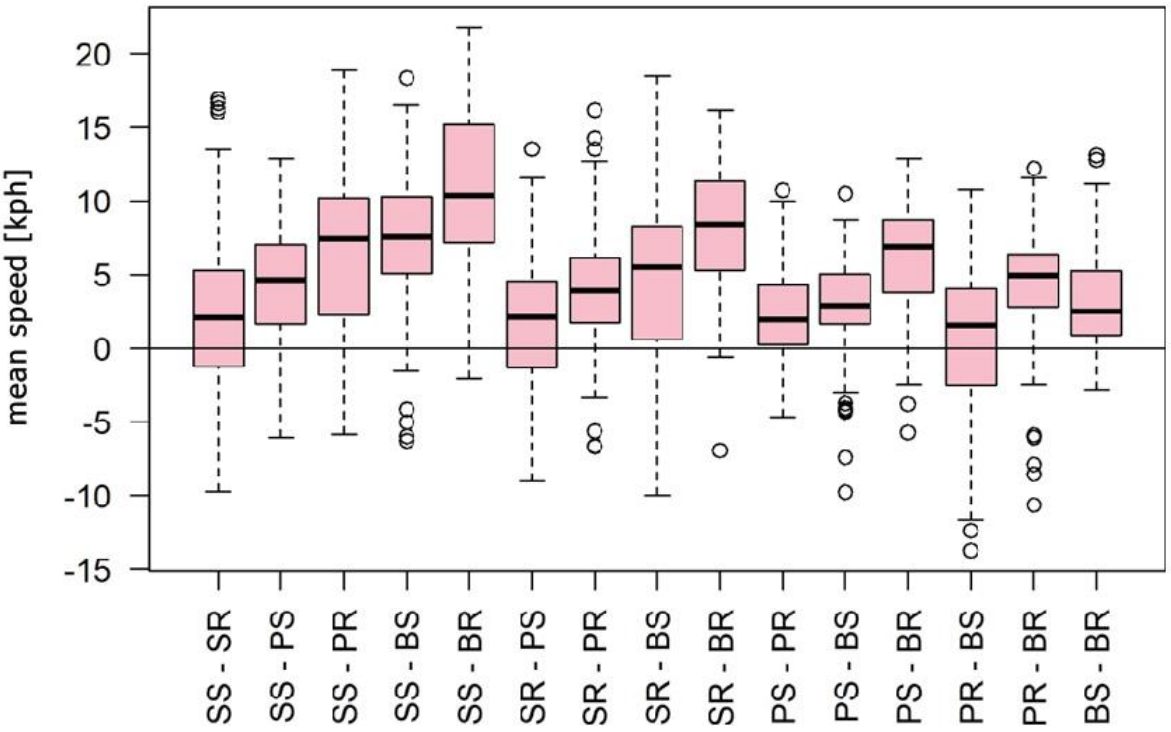


Figure 6. Mean difference of personal speed levels with different bicycles[6].

The second question to be answered is if the mean speed of speed pedelecs and conventional bikes differ significantly when riding in different styles (relaxed or sporty) on the same infrastructure. Therefore, we randomly split the sample in two groups and compared the mean speed of conventional bikes and speed pedelecs in both ways of riding which resulted in comparing four groups: SS - BS, SS - BR, SR - BS, SR - BR (Figure 7). To answer the question, we use the Welch two sample t-test with a level of significance of 0.05. To adjust for multiple comparison, we use Holm correction. In Table 2, one can see that the differences between the groups are significantly greater than zero and that the adjusted p-values are very low. Figure 7 provides an overview of the comparisons of the four groups. The smallest difference between two groups can be found between a speed pedelec in relaxed riding and a conventional bike in

[6] negative values occur when a participant rides at a higher speed with a minor combination, e.g. pedelec-relaxed < bike-sporty

sporty riding. Looking at the three other comparisons, the gap between the mean speed is much larger with the largest difference between a sporty ridden speed pedelec and a relaxed ridden conventional bike.

Table 2. Results of Welch two sample t-test with Holm correction of four pairs with different types of bicycles and different riding styles.

Pair	Mean speed (S)	Mean speed (B)	Test statistic	Df	P-value
speed pedelec sporty – conv. bike sporty	29.4	22.28	7.53	92.92	1.60×10^{-11}
speed pedelec sporty – conv. bike relaxed	29.4	18.47	12.36	83.43	7.6×10^{-21}
speed pedelec relaxed – conv. bike sporty	27.35	22.28	5.8	97.43	4.08×10^{-8}
speed pedelec relaxed - conv. bike relaxed	27.35	18.47	11	89.99	1.24×10^{-18}

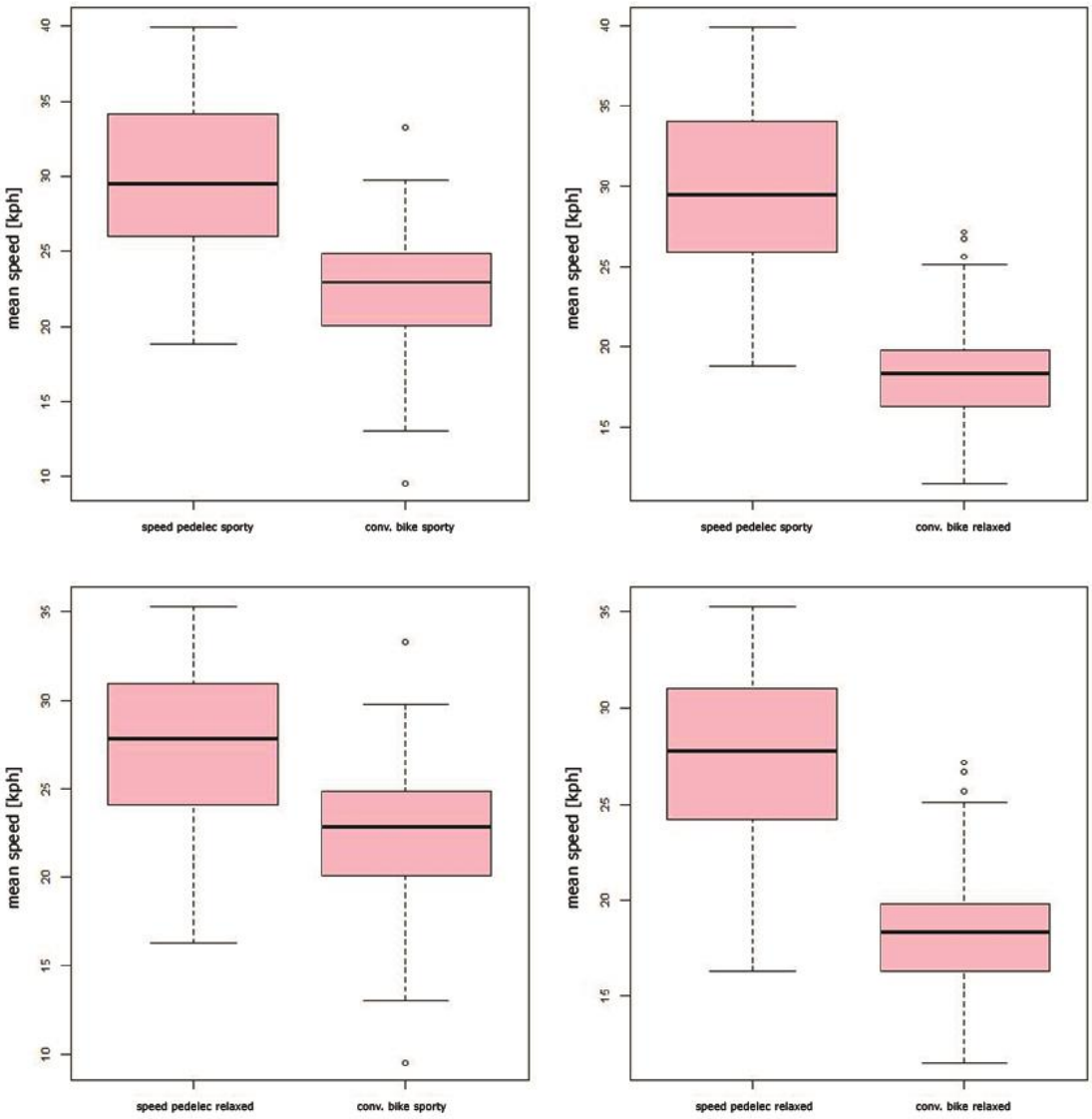


Figure 7. Mean speed of conventional bikes and speed pedelecs in different riding styles.

3.3 Results of the questionnaire

In the questionnaire the 101 participants of the test rides were asked several questions on different topics right after their ride with the three different types of bicycles. A full version of the questionnaire can be found in the appendix.

In question 1 (Figure 8) the participants were asked, how many days a week they usually use a bike in their workday life and in their leisure time. More than 50% stated, they would use a bike

three or more times a week in their workday life, only about 34% said the same for leisure time. 12% use a bike once or twice a week in workday life while 18% said, they would use a bike less than once a week. 17% did not answer this question. The answers to the bike use in leisure time are more equally distributed, 25% use their bike once or twice a week, 30% less than once and only 12% did not answer the question.

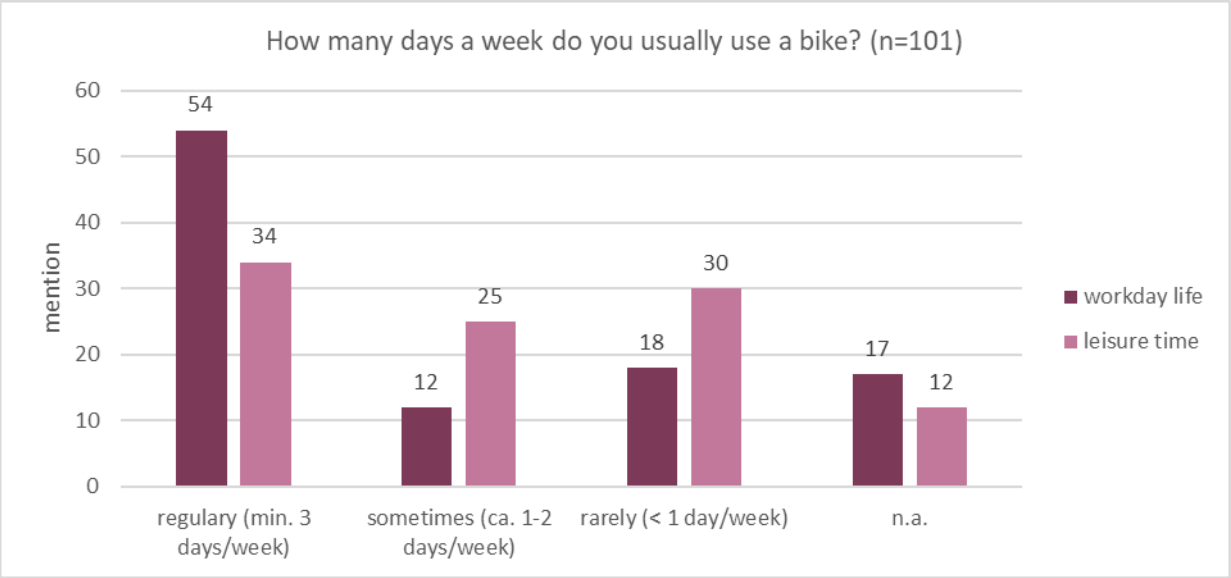


Figure 8. How many days a week do you usually use a bike?

In question 2 (Figure 9) the participant should give an insight on their previous experience with pedelecs or speed pedelecs. 62% had used a pedelec before while only 4% said the same for the speed pedelec.

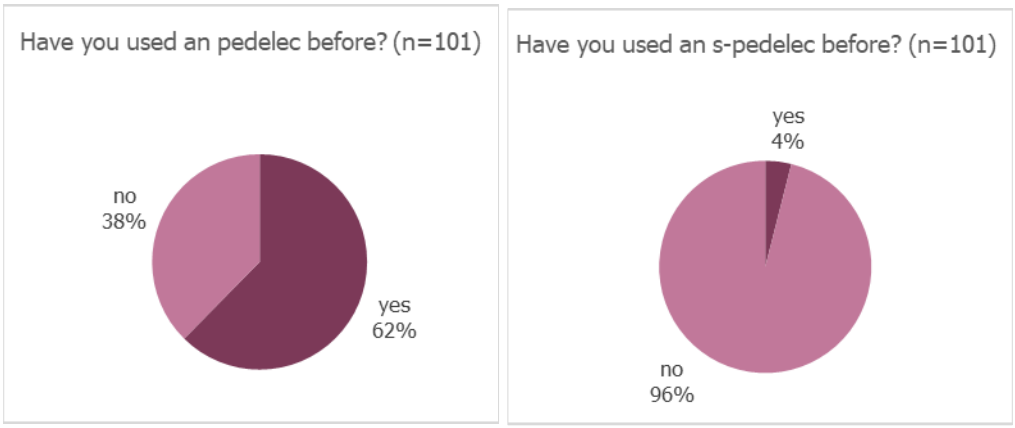


Figure 9. Have you used a pedelec or a speed pedelec before?

It is therefore not surprising that only 12 participants own a pedelec and none of the them owned a speed pedelec (question 3).

In question 4 (Figure 10) we wanted to know, with which of the three different types of bicycles the subjective level of safety of the participant was the highest. Almost 60% stated they felt safest while riding a pedelec, 37% answered the same for the conventional bike and only 5% for the speed pedelec.

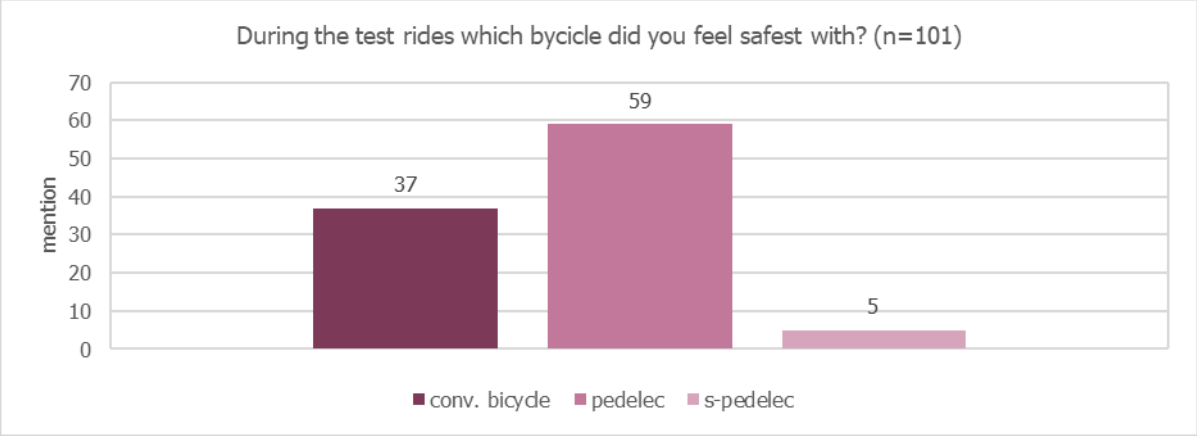


Figure 10. During the test rides, which bicycle did you feel safest with?

The results for question 5 (Figure 11.) “which type of bicycle did you perceive the most comfortable?” are quite similar. 80% of the participants voted for the pedelec, 16% for the speed pedelec and only 5% stated that they felt most comfortable with the conventional bike.

Figure 11. During the test rides, which bicycle did you perceive most comfortable?

Question 6 (Figure 12) addresses the benefits of a pedelec or a speed pedelec compared to a conventional bike. The suggested answers “supports you riding uphill”, “comfort/less physical effort” and “greater speed” were mentioned 94, 78 and 40 times, respectively. The most frequently mentioned answer that was not suggested was “covering greater distances” with 9 mentions.

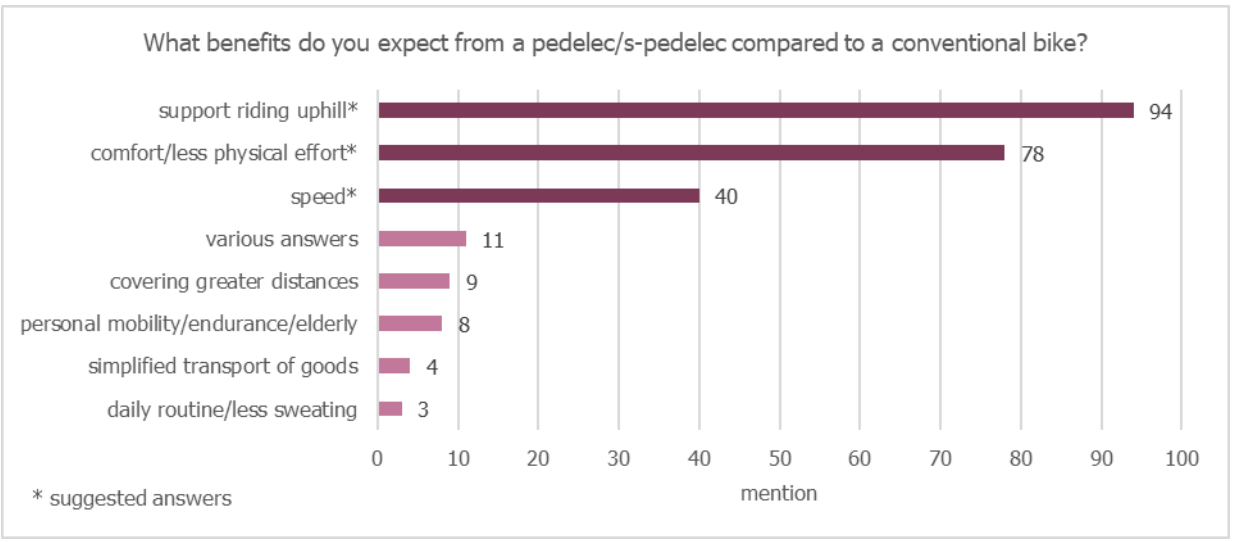


Figure 12. What benefits do you expect from a pedelec/ speed pedelec compared to a conventional bike?

The final question of the questionnaire (Figure 13) deals with the personal opinion of the participants on the impact of bicycles with pedalling assistance on traffic safety, for oneself as

well as for other road users. 82% think that pedal assisted bicycles could have an impact on traffic safety for other road users. The most mentioned comments to this question were: “hard to estimate the actual speed of the cyclist/underestimate the speed of the cyclist” (37 times), “cyclists are not used to this kind of bicycle/cyclists overestimate their personal abilities” (19 times) or “conflicts with pedestrians on shared infrastructure are likely to happen” (19 times). In contrast to that only slightly more than 60% think that these kinds of bikes would affect their personal safety in traffic. The most frequently mentioned comments are: “I ride as carefully as before”, “cyclists are not used to this kind of bicycle/cyclists overestimate their personal abilities” or “increased accident risk/increased risk in an urban environment”.

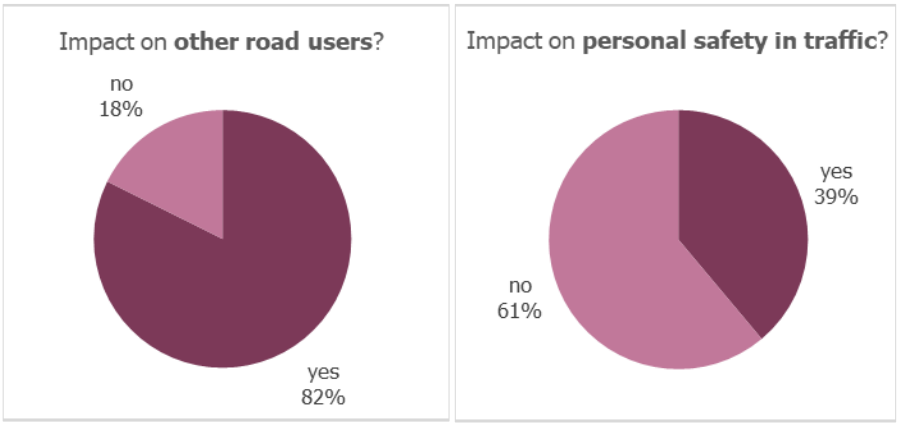


Figure 13. Pedelecs or speed pedelecs have the potential to drive faster. Do you think that there is an impact on the road safety?

4 CONCLUSIONS AND DISCUSSION

This study focuses on the interpretation of the different riding speeds and of the differences between the riding speeds of conventional bikes, pedelecs and speed pedelecs.

A result of this study is the statistically significant difference between the mean riding speed of participants riding either a conventional bike, a pedelec or a speed pedelec, implying that people do not have a kind of comfortable speed zone they do not leave no matter which type of bike

they are riding. A second result of this study is that the mean riding speeds of groups riding a conventional bike or a speed pedelec in either a relaxed or sporty way differ significantly, implicating that road users ride with a different speed level on the same infrastructure.

Having a look on the overall median speed displayed in Figure 3, we can see that the riding speed of the three types of bicycles is quite different, participants rode with a speed pedelec more than 5kph faster than with a conventional bike. Unlike that, males and females and people from different age groups ride on very similar speed levels. This indicates that the differences between riding speed results from the type of bicycle someone chooses. Looking at Figure 4, similar conclusions can be drawn. In each of the 7 sections of the test track, the median speed of speed pedelecs is larger than the median speed of conventional bikes and of pedelecs while the median speed of pedelecs is larger than the median speed of conventional bikes. The largest differences can be found on the straight sections where the participants were asked to ride in a sporty or relaxed way as well as in the ascending section. The median speeds of the three types of bikes are most similar at the turning point and in the descending section.

When testing the hypothesis that people choose a different speed level with a speed pedelec and with a pedelec or a conventional bike, we only use the results at the straight sections leaving the other sections becausee of practical and statistical reasons aside. First, the analysis of the straight sections is of main interest and second, comparing all types of bicycles and sections would lead to far larger adjusted p-values when correcting for multiple testing. By using a paired t-test we showed that the mean[7] of the speed differences between riding speeds using the three different types of bicycles are significantly (α=0.05) greater than zero. To make this clearer, we compared the mean speed differences of the three bicycles ridden by the same participant. **This**

[7] Median speed was used for the figures while mean speed was used for the calculations.

means that a person does not have some kind of safe speed zone no matter which type of bicycle he/she rides but that the type of bicycle actually influences someone's riding speed.

Furthermore, we tested if independent groups of participants ride with different types of bicycles in different riding styles at significantly different speeds. Therefore, the sample was split randomly into two independent groups which were compared against each other. By using a Welch two sample t-test, it turned out that mean riding speed of conventional bikes and speed pedelecs ridden in a sporty or relaxed way actually differ significantly. How large these differences can get we can observe when we look more deeply into the data displayed in Figure 5. The difference between the median of the maximum speed of a conventional bike and a speed pedelec is about 10kph while the difference between the median of the maximum speed of a conventional bike and the maximum speed of the speed pedelec is more than 20kph (max. speed speed pedelec sporty: 46.8kph). Taking into consideration that the half of the people ride slower than 20.2kph with a conventional bike, the speed difference between a very fast speed pedelec rider and a relaxed conventional bike rider can get really large. At this point, we suspect that the level of traffic safety decreases when bike riders with such large speed differences ride on the same infrastructure.

Looking at the results of the questionnaire, we see that most of the participants are quite experienced cyclists. About two third of the participants use a bike in workday life and more than 50% in leisure time at least once a week. It can be assumed that this amount of regular practice is enough to not influence the results of the test rides in terms of inexperience of the participants. On the other hand, the participants are not too experienced with pedal assisted bicycles either. More than 60% have tested a pedelec before but only 4% stated the same for a speed pedelec. Only 12 participants own a pedelec and none of them owns a speed pedelec.

The participants perceived the pedelec as the safest and most comfortable of the three tested bicycles. Some reasons may be that the pedal assistance is very comfortable, and the maximum assisted speed is ideal for cycling in an everyday life use. At this point ii has to be mentioned that one minor downside of the study design was that the tested pedelec and speed pedelec were different in terms of brand and design. When people liked riding this certain type of pedelec it is not unlikely that they perceived the speed pedelec less safe or comfortable. Besides this, the need to wear a helmet is a disadvantage of the speed pedelec in the opinion of the participants.

As benefits of a bicycle with pedalling assistance, the participants mentioned the support riding uphill 94 times and the overall comfort including less physical effort 78. Another 9 and 8 times, respectively, the participants mentioned “covering greater distances” and “personal mobility/endurance”. The comfort and support of such a bicycle seem to be a huge motive. “Speed” was also mentioned 40 times but considering the answers to the questions discussed before, the maximum speed of a pedelec seems to be adequate for the participants.

The answers to the last question are very interesting in terms of traffic safety on the one hand and in terms of the difference between self-perception vs. perception of others on the other hand. 82% of the participants stated that pedal assisted bicycles could have an impact on the traffic safety of other road users while only about.40% stated that they could have an impact on their own safety. Participants stated that it is hard to estimate the actual speed of the cyclist or that the cyclists are not used to pedal assisted bicycles and that there is a lack of practice.

In summary, it can be stated that the mean riding speed of a person depends on the type of bicycle and that independent groups of people ride with different speed on different bicycles. If these speed differences are too large, it is suspected that the level of traffic safety decreases.

The topic of decreasing traffic safety should be subject to further research. It would be interesting to observe and analyse how users with different types of bicycles behave in the same

mixed traffic environment and whether this mix of vehicles has an effect on traffic safety: Which, if any, conflicts occur, is the overall speed level affected and does the subjective level of safety of the participants change?

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APPENDIX

Questionnaire

1. How many days a week do you usually use a bike?

	workday life	leisure time
regulary (min. 3 days a week)	○	○
sometimes (ca. 1 – 2 days a week)	○	○
rarely (< 1 day a week)	○	○

2. Have you used a pedelec and or a speed pedelec before?

	Yes	No
Pedelec	○	○
Speed pedelec	○	○

3. Do you own a bike with pedalling assistance?

	Yes	No
Pedelec	○	○
Speed pedelec	○	○

4. During the test rides which bicycle did you feel safest with?

	1. Place	2. Place	3. Place
Conventional Bicycle	○	○	○
Pedelec	○	○	○
Speed pedelec	○	○	○

5. During the test rides which bicycle did you perceive most comfortable?

Conv. Bicycle ○

Pedelec ○

Speed pedelec ○

Reason: _____

6. What benefits do you expect from a pedelec/speed pedelec compared to a conventional bike?

Comfort/Less physical effort ○

speed ○

support riding uphill ○

other: ○

7. Pedelecs or speed pedelecs have the potential to drive faster. Do you think that there is an impact on the road safety?

Impact on personal safety:	
Impact on other road users:	