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Priority behaviour of cyclists at crossings with and without priority markings

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Summary

This research investigates the influence of priority road markings on cyclists' behaviour at bicycle street crossings. Almost all bicycle street crossings are controlled by priority markings or by the priority rule: traffic coming from the right has priority. At these crossings there is a lot of interaction between cyclists, so it is important that the bicycle traffic can pass the crossings without severe conflicts. For the research two crossings were observed. One crossing with priority markings and one without priority markings, both with traffic from four directions.

At both crossings a camera recorded the cyclists passing the crossing for one hour at three different moments in the day. The conflicts on the footage are investigated in the analysis. Firstly, It was investigated if priority was given when it should have been given. Also the severity of the conflicts and the behaviour of the cyclists who had to give priority were classified. Finally the influence of the kind of crossing (crossing or merging), the influence of groups and the influence of scooters were addressed.

The results show no relation between the presence of a scooter in a conflict and the percentage of cyclists not giving priority while they should have given priority. Also merging and crossing conflicts show no large difference in priority behaviour. But when groups are part of a conflict, priority is less often given while it should have been given. After these three influences, conflicts in general are compared for a crossing with priority markings and a crossing without priority markings. The observed crossing without priority markings shows a larger percentage of severe conflicts. Also the cyclists who had to give priority show more often reckless behaviour in conflicts. From these results it is concluded that priority markings control the priority on a crossing better than the priority rule: traffic coming from the right has priority.

Contents

1. Introduction

At a shared space or at a crossing of two bicycle paths, road markings are often used to give priority to one direction. But there are also crossings without these road markings. When this is the case, the basic rules of traffic step in (traffic from the right has priority). Cyclists may or may not obey the priority markings and cyclists can also give or not give priority to traffic from the right. For both scenarios there is no scientific proof in practise. So bicycle traffic at crossings should be observed to find out how cyclists react to priority markings or to crossings without markings. Then it can be determined if rule compliance at crossings is higher for crossings with or without priority markings.

Research shows that more severe accidents have a higher chance of getting registered and registration of accidents is a lot higher when a motorized vehicle was part of the accident (SWOV, 2016). This indicates that there is not a lot of information available on accidents between bicycles. Other research confirms this by stating that there is no recent Dutch research into safety of bicycle paths and no knowledge of safety of cyclists at certain crossings (Reurings, Vlakveld, Twisk, Dijkstra, & Wijnen, 2012).

The municipality of Delft is running a large mobility project of which bicycle traffic is an important aspect ("Fietsers baas op fietsstraat," 2018). Important goals of the project that concern cyclists are: more space for cyclists, more comfort for cyclists and creating a bicycle network with the possibility for cyclists to take different routes. So the municipality benefits from this research, because it can have an influence on how new roads will be designed. Therefore the role of priority markings should be analysed so further research can help with improving the safety and flow of bicycle crossings. Other municipalities also take an interest in this research for the same reasons. Furthermore the institute SWOV that conducts scientific research into traffic safety is contacted, because they can contribute to the methodology of the research with their knowledge. SWOV can also continue the research with the results from this report.

Other stakeholders in the project are the cyclists who are using the investigated bicycle paths, but also all other cyclists because every cyclist encounters crossings when they are using the roads.

The research is focused on crossings of two bicycle paths. Two kinds of crossings are analysed. One with priority markings and one without priority markings, as is shown in figure 1 and 2. The focus is on situations when two or more cyclists cross paths and if priority is given or not given while it should be given. Intensity and riding direction are influential factors that are taken into account. There can also be other factors that influence the cyclists on a crossing. Those are discussed in the chapter Methodology. A possible influence on priority behaviour of scooters, groups and crossing or merging conflicts is addressed as well. Priority behaviour is here defined as the likelihood of cyclists to give priority or not give priority while they should have given priority.

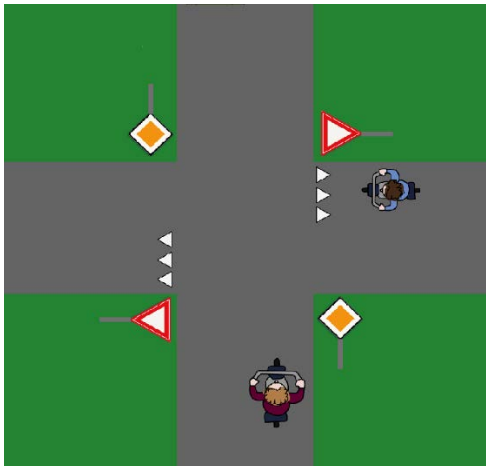


Figure 1: Crossing with priority markings

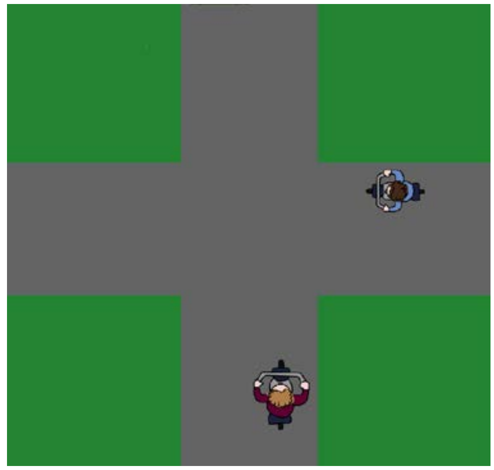


Figure 2: Crossing without priority markings

The goal of this research is to gain knowledge about the influence of priority markings at bicycle street crossings. With that knowledge the following research question can be answered:
What is the influence of priority road markings on priority behaviour of cyclists where bicycle streets cross?
The influence of road markings is investigated by comparing conflicts on two kinds of crossings shown in figure 1 and 2. It is expected that the priority markings have a bigger influence on cyclists than the basic rule: traffic from the right gets priority. That should then result in less severe conflicts when priority markings are present. The results of this research can contribute to an extension of knowledge about bicycle paths regarding infrastructural design, traffic flow and safety.

In the next chapter a literature review is given on conflict observation. The third chapter ''Methodology'' uses the literature review from the second chapter to formulate how the observations and analysis will be performed. In the chapter ''Results and Discussion'' the results of the observations are visualised and discussed. Finally the fifth chapter concludes the research and recommendations for further research are given.

2. Literature review on conflict observation

Before the crossings will be observed, it should be clear what information will be extracted from the footage and how the analysis will be executed. This chapter discusses conflict observation methods from other research and the methods that are used in reference projects.

Research shows that 'trafficconflicttechniques' can be split into two groups (de Jong, Gysen, Petermans, & Daniels, 2007). The first group uses measurable indicators such as 'post encroachment time' and 'time to collision' in traffic models and simulations.

- Time to collision: the time that is left until an accident occurs if the road user stays on the same route with the same speed.
- Post encroachment time: the time between a vehicle passing a spot on the road and a second vehicle arriving at that same spot.

Other research calls these indicators for traffic safety 'surrogate safety measures' (Gettman & Head, 2003). Besides the two surrogate safety measures mentioned above the following four are proposed:

- Maximum speed of the two vehicles (MaxS).
- Maximum difference in speed of the two vehicles during the conflict event (DeltaS).
- Initial DR (Deceleration Rate) of the reacting vehicle.
- Location of the starting and ending points of the conflict event (CPL (Conflict Point Location), CLSP (conflict line starting point), and CLEP (conflict line ending point)).

An undesirable situation occurs when the following requirements are satisfied:

- One of the vehicles must take evasive action to avoid a collision.
- The resulting surrogate measures exceed significant values.

The Surrogate safety measures are intended for motorized vehicles. So when it will be applied for bicycle traffic the indicative values that determine if a situation is undesirable should be adjusted. Furthermore, these indicators are intended for simulations of traffic situations, so if footage from a crossing is used to determine the surrogate safety measures, the data will be more realistic but less accurate.

These indicators can give numerical results for conflicts which can be used for a comparison of the crossings. But it is a time-consuming process because every interaction between road users should be addressed in detail. Finally the surrogate measures are an indicator for safety, so the influence of priority markings can only be interpreted from their results.

The second group of 'trafficconflicttechniques' from the first mentioned research is described with the following statements (de Jong et al., 2007):

- Focused on determining indicators that can be measured during the observation and focused on the way the observation can be performed.
- Related to the design of the road.
- Used in situations where traffic comes from different directions.
- Also suited for slow moving traffic like cyclists and pedestrians.
- The technique is very practical; focused on observations and drawing conclusions related to policy and design.

This is a more practical technique based on the observations of the observer. Two reference projects will be discussed that used this technique for similar research projects.

Firstly, a research project was conducted in Amsterdam in 2014 (te Brömmelstroet, 2014). For the research nine crossings were recorded with the purpose of observing cyclists behaviour. The 'Desire Lines Analysis Tool' is used for the analysis of the footage. This tool maps different routes across the intersection from every direction and shows the number of cyclists for every route. An example is shown in figure 3. The cyclists are also classified in three groups:

- 'Conformists': Cyclists who follow the rules and stay on the designed routes;
- 'Momentumists': Cyclists who do not completely follow the rules and take a different route than the design of the crossing intended for them without causing severe conflicts or dangerous situations for others;
- 'Recklists': Cyclists who ignore the rules and thereby cause a conflict or a dangerous situation for others.

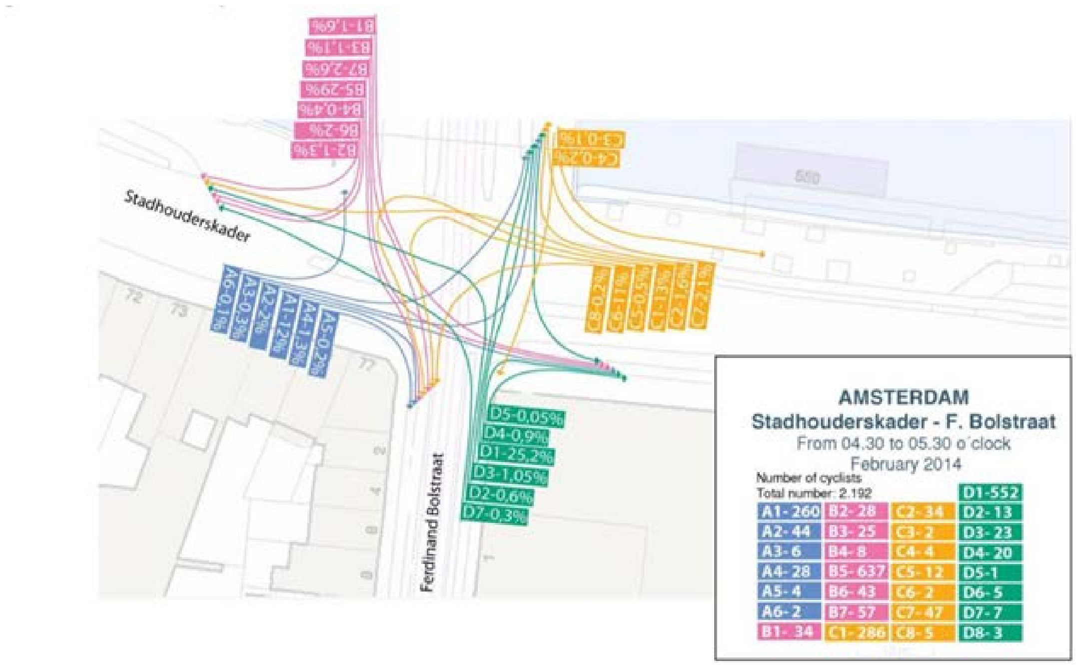


Figure 3: indication of results for riding direction and number of cyclists per direction (te Brömmelstroet, 2014)

In another reference project behaviour of cyclists on a bicycle road and a bicycle road crossing was recorded on camera and then analysed (de Hair-Buijssen, van der Horst, & en Scheepvaart, 2012). The researchers were searching for possibilities to increase safety for cyclists. Behaviour of cyclists and conflicts were analysed with the observation method DOCTOR (Dutch Objective Conflict Technique for Operation and Research) (Kraay, der, & Oppe, 1986). With this method the severity of a conflict is rated by the observer from 1 to 5. The surrogate safety measures 'post encroachment time' and 'time to collision' are calculated to support the rating of the conflict made by the observer. However this last step was not done in the reference project.

Mapping the routes across a crossing and counting the cyclists per direction would create a better understanding of the observed crossings, but it would take a lot of time. Classifying cyclists would create a better understanding of the cyclists' behaviour at a crossing and can be linked to the influence of priority markings. This is also the case for the rating of conflicts of the DOCTOR method.

3. Methodology

This methodology gives a thorough description of how the observations and analysis are performed. Firstly the equipment that is needed for the observations is mentioned. Secondly the execution of the actual observations are described. Finally the analysis is discussed which includes the information that is obtained from the observations.
To improve the quality of the research Gert-Jan Wijlhuizen and Atze Dijkstra of SWOV were interviewed on 12 September 2018. There will be referred to the interview at parts of the methodology where the external experts contributed.

3.1 Observations

The following equipment was used during the observations:

- Camera (GoPro: Denver Wifi Cam, shown in figure 4)
- power bank
- Smartphone with GoPro-app to control the camera (Denver Action Cam 2)
- GoPro mount and strap to attach the camera on an object at the observation location.
- Notepad to catalogue observations

Figure 4: Denver GoPro camera

The cameras, attachment gear and power bank were provided by the Transport and Planning department of the Civil Engineering faculty of the Technical University of Delft. The cameras have a battery capacity of approximately one hour. But by plugging in a power bank, it can be extended. The cameras record for a period of approximately thirty minutes. So for an observation of one hour, the camera should be started again after half an hour.

Two crossings need to be chosen for the observations. One crossing with priority markings and one crossing without priority markings. Besides the priority markings the crossings need to be as similar as possible for the comparison to be as accurate as possible, because road markings are not the only factor that influence priority behaviour (interview, 12 September, 2018). Other factors could be the intensity of the cyclists, the speed of the cyclists, the riding directions, objects near the crossing, size of the crossing and a slope in the road. Also a high intensity is required to make sure there is enough data to analyse.
The search to a suitable crossings for this research was limited to Delft. The crossing with priority markings was chosen based on a high intensity and limited external factors. For the other crossing multiple alternatives were found and the most suitable crossing is chosen. These are limitation due to the short time that is available for the research.

The crossing with priority markings is the crossing shown in figure 5. There are two factors that could influence the priority behaviour of the cyclists. These factors are the busses that pass on the road next to the crossing and the slope of the bicycle path in the figure on the right. So those factors need to be taken into account.
A similar crossing without priority markings then needed to be chosen. Figures 6 to 10 show the alternatives from which the crossing is chosen. The crossing from figure 6 is not suitable because of a low intensity from the Balthasar van der Polweg. Also a hardened surface next to the crossing leads to a lot of shortcuts and therefore even less interactions.

Figure 5: Mekelweg – Kruithuisweg

Figure 6: Mekelweg - Balthasar van der Polweg

The crossing from figure 7 had only 9 interactions between 8:28 and 8:35. During less busy times that number will be even less, so due to low intensity this crossing is also inadequate. Figure 8 shows a crossing which has also a low intensity from one direction (the Industriestraat) which makes it unsuitable.

Figure 7: Kruithuispad - Victoriapad

Figure 8: Industriestraat - Mercuriusweg

The layout of the crossing in figure 9 is very different from the crossing in figure 5. If the intensity from one direction of the crossing in figure 5 would be very low, the two crossings could be compared because both crossings would have cyclists from only three directions. But since this is not the case the crossing from figure 9 is too different and therefore inadequate. Finally the crossing in figure 10 has two external influences that are not desired. Cars can drive over the roads from three directions and a bridge next to the crossing can open which could interfere with the bicycle traffic as well. Between 8:05 and

8:25 24 cars were observed with a maximum passing time of 10 seconds. Because of an almost constant flow of bicycle traffic that leaves enough time without cars. The opening of the bridge and the clearing of the crossing takes a couple of minutes. Leaving out the moments when the bridge is open or when cars are driving on the crossing, there is still enough usable footage for the analysis. And therefore the crossing without priority markings from figure 10 is chosen for the observations. The chosen crossings are referred to as ''Crossing With'' (figure 5) and ''Crossing Without'' (figure 10).

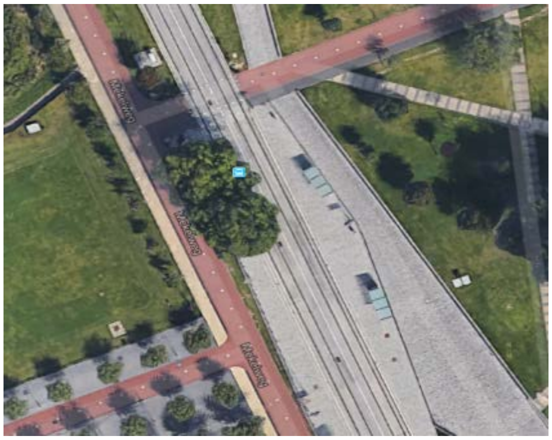


Figure 9: Cornelis Drebbelweg - Mekelweg

Figure 10: Abtswoudseweg - Zuideinde

Before the observations can be done, a trial run is performed to make sure the real observations run smoothly. Two main goals for the trial are:

- Get used to the camera and the app on the phone on which the recording footage can be controlled.
- Find the best spot to hang the camera (at both crossings).

The best spot is high above the ground for a good overview of the crossing and at the opposite side of the crossing from where the observed cyclists are coming from.
Another important remark is the fact that the largest traffic flows are different for different times of day. Therefore each crossing is recorded during the morning rush hour, an off-peak hour and the afternoon/evening rush hour. This provides varied data to analyse.
Recording moments are:

- Morning rush hour: 08.00 – 09.00
- Off-peak hour: 10.00 – 11.00
- Afternoon/evening rush hour: 17.00 – 18.00

While the camera is recording, the observer catalogues conflicts between cyclists so they are easier to trace on the footage later on. After every half-hour the camera should be started again as it stops recording after approximately half an hour.

Recording in public is in principle allowed in the Netherlands. Nonetheless it is important that the footage is dealt with in a professional way. So it is only used for this research and it will not be put online.

3.2 Analysis

The goal of the analysis is to gain information from the footage. With the results of the analysis the research question is then discussed. For both crossings the following information is obtained from the footage:

- Are the cyclists merging or crossing each other?
- Is it a conflict between cyclists, between a cyclist and a scooter or between scooters (interview, 12 September, 2018)?
- Is it a conflict between two individuals, between a group and an individual or between two groups?
- Is priority given or not given while it should be given?
- What is the severity of the conflict according to the DOCTOR method (Kraay et al., 1986) (0,1,2,3,4 or 5)?
- What is the class of the cyclists that have to give priority according to the reference project (conformist, momentumist or recklist) (te Brömmelstroet, 2014)?

The DOCTOR method investigates the conflicts according to the behaviour of the cyclists who have priority. The classification by conformists, momentumists and recklists investigates the behaviour of the cyclists who have to give priority. By using both methods a more complete picture of the conflicts can be drawn.

There are some issues concerning the obtainance of the information that need further explanation. Firstly the definition of a conflict should be clear. For this research the definition of the DOCTOR method is used (Kraay et al., 1986). According to the method, a conflict is a situation in which two or more traffic users approach each other in time and space which causes a mutual influence of behaviour.

Secondly it is important to declare that the DOCTOR method has a range of 1-5. The extra class ‘’0’’ is added for this research to also log conflicts in which the cyclist who has priority does not need to react. The severity of the conflicts can be classified according to the following descriptions:

0. There is an interaction. The cyclist who has priority does not have to react. The cyclist who has to give priority does that without causing a dangerous situation.
1. The cyclist who has priority brakes lightly as a reaction to the cyclist who has to give priority.
2. The cyclist who had priority has to brake or swerve as a reaction to the cyclist who has to give priority.
3. The cyclist who has priority has to brake hard or swerve severely as a reaction to the cyclist who has to give priority.
4. The cyclist who has priority has to brake very hard or swerve severely as a reaction to the cyclist who has to give priority. The cyclists almost collide or even collide lightly without damage or injuries.
5. There is a collision after hard braking or swerving.

Another issue concerns groups including scooters. When there is a group involved in a conflict there is looked at the person in the front, because that person interacts with the traffic from another direction. But if for example a group is giving priority to an individual by braking, but another person in the group decides to overtake the first person in the group. And thereby he or she causes a dangerous situation by crossing the intersection while priority had to be given. The situation is registered as two conflicts; one in which the group gives priority and one in which the group does not give priority. There is another issue in regard to groups to take into account. It is important to make a distinction in the analysis

between groups having priority over individuals and individuals having priority over groups. So both types of conflicts are registered separately.
Finally the difference of intensity at both crossings is taken into account when the crossings are being compared. It was recommended to map every cyclists by the direction from which they came and the direction in which they were going (interview, 12 September, 2018). This was also done in the reference project mentioned in the previous chapter (te Brömmelstroet, 2014). But because it would have taken too much time, the number of cyclists are counted for a period of 15 minutes at both crossings to get an indication of the intensity. The results of the counts are shown in figure 11 and figure 12 with the numbers of cyclists in black and the direction numbers in white. The main flows of Crossing With are from 4 to 1 and from 1 to 3. For Crossing Without the main flows are from 1 to 2 and from 4 to 2. Of the 107 cyclists at Crossing Without 50 went straight or turned left and thereby crossed the path of the cyclists coming from direction 1. It is also observed that the intensity drops a lot further at Crossing With at off-peak times than at Crossing Without. For the comparison between both crossings, the number of conflicts need to be as close as possible. Therefore, conflicts between directions 1-2, 1-4, 3-2 and 3-4 are analysed at crossing With and conflicts between directions 1-2 are analysed at Crossing Without.

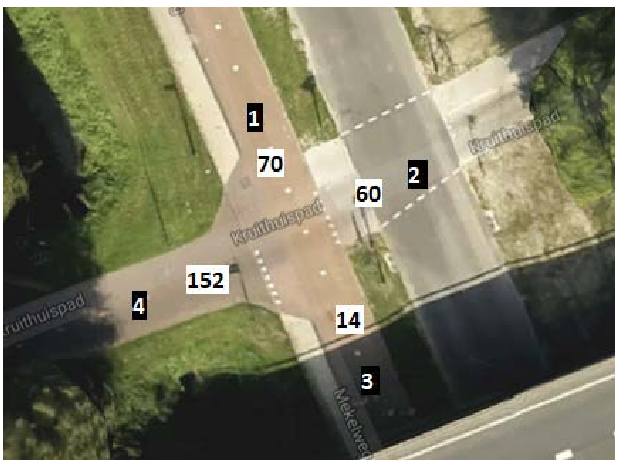


Figure 11: Intensity at Crossing With

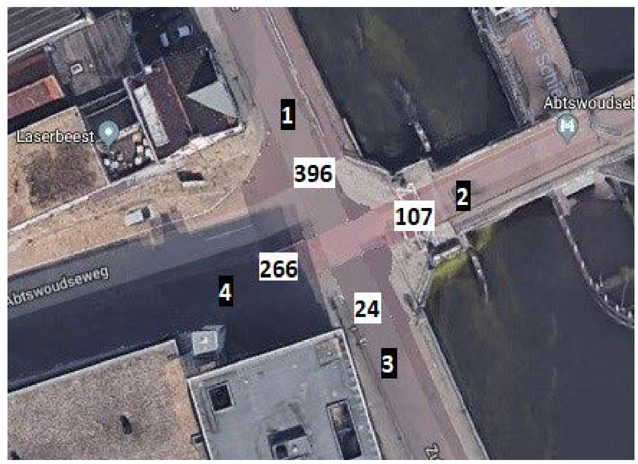


Figure 12: Intensity at Crossing Without

For both crossings there are factors to take into account, because they could have an influence on the behaviour of the cyclists and therefore also on the results of the analysis. The factors are listed below:

- Crossing With:
  - Pedestrians cross the road. Stop analysing when the pedestrians are on the road.
  - Signal lights for a passing bus go on which stops the traffic flow of direction 2. Start analysing again when the signal lights go off.

- Crossing Without:
  - Pedestrians cross the road. Stop analysing when the pedestrians are on the road.
  - Signal lights for the opening bridge go on. Start analysing again when the crossing is cleared from the congestion caused by the closed bridge.
  - Cars (or other four wheel motorized vehicles) are on the crossing.

For the cars on Crossing Without it should be clear when the analysis should be stopped. It should be the moment when the cars interfere with the bicycle traffic on the crossing. This boundary is assumed to be at the orange lines on the road just before the crossing. In figure 13 an orange line in one direction is shown. These lines are in all three directions were cars are allowed to drive (directions 1, 3 and 4 in figure 12). The influence on the cyclists before the orange line is little, because the speed of the cars is very low (same speed as the cyclists). After crossing the orange line the cars will either wait in front of the intersection or immediately cross the intersection. When a car is waiting, the analysis should be stopped because cyclists from the same direction need to get around the car. And when a car crosses the intersection the analysis should be stopped because there is an interaction between the cyclists coming from other directions.

Figure 13: Orange line on the road at Crossing Without

4. Results and Discussion

In this chapter the results of the analysis are discussed. The results can be found in Appendix A and the processing of the results can be found in Appendix B. In the first paragraph are the results of the conflicts focussed on priority, severity and the classification of the cyclists. The priority behaviour and the influence of priority markings is addressed by discussing these results which is the main focus of the research. Next conflicts with scooters, conflicts with groups and merging conflicts are discussed to address their influence on priority behaviour. In every paragraph the results are first shown and shortly explained, followed by a discussion of the results.

4.1 Conflicts

For every conflict several factors are determined which is explained in the methodology. The factors priority behaviour, conflict severity and classification of the cyclists who needed to give priority are discussed in this paragraph. A statistical test is performed to investigate the influence of priority markings. This test is only performed for the factor priority behaviour, because this factor is closest related to the priority markings.

Firstly, the results for the number of times priority is given and priority is not given while it should be given are shown in figure 14. The priority markings at Crossing With control who has priority at that crossing. From the 204 conflicts that were observed at Crossing With, 90 % of the cyclists who had to give priority did so. At Crossing Without the cyclists from the right have priority and from 158 conflicts 61% gave priority when they had to.

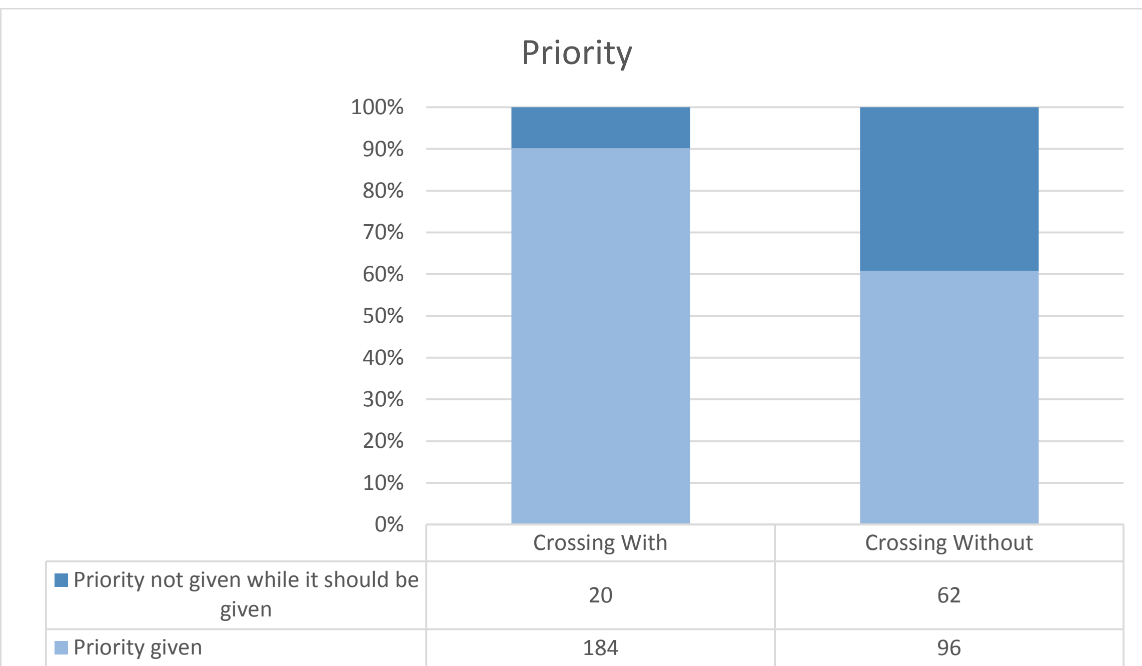
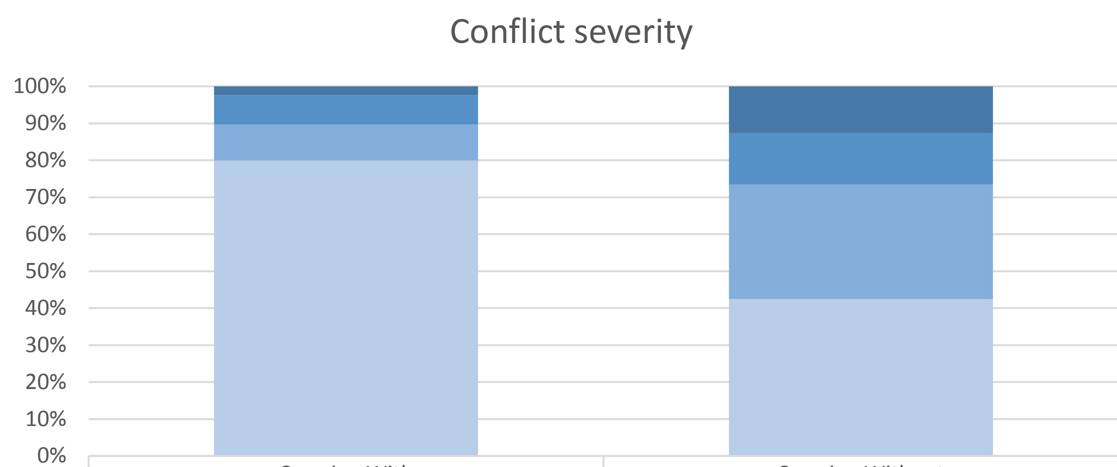


Figure 14: Results priority (not) given

A statistical test is performed on the results from figure 14 to investigate the relation of priority behaviour at the crossings. The crossing and the priority behaviour both have two categories: priority given/priority not given and a crossing with priority markings/a crossing without priority markings.

Therefore the chi-squared test can be used which accepts or rejects a null hypothesis based on a calculation (Heijnen, 2008). The null hypothesis is: there is no relation between the priority behaviour and the presence of priority markings. A chi-squared value is calculated and if this value is higher than 3.841, the null hypothesis is rejected. For the results the chi-squared value is 44.035 and therefore the null hypothesis can be rejected. So this indicates that priority markings influence the priority behaviour of cyclists. The calculation of the chi-squared value can be found in Appendix B.

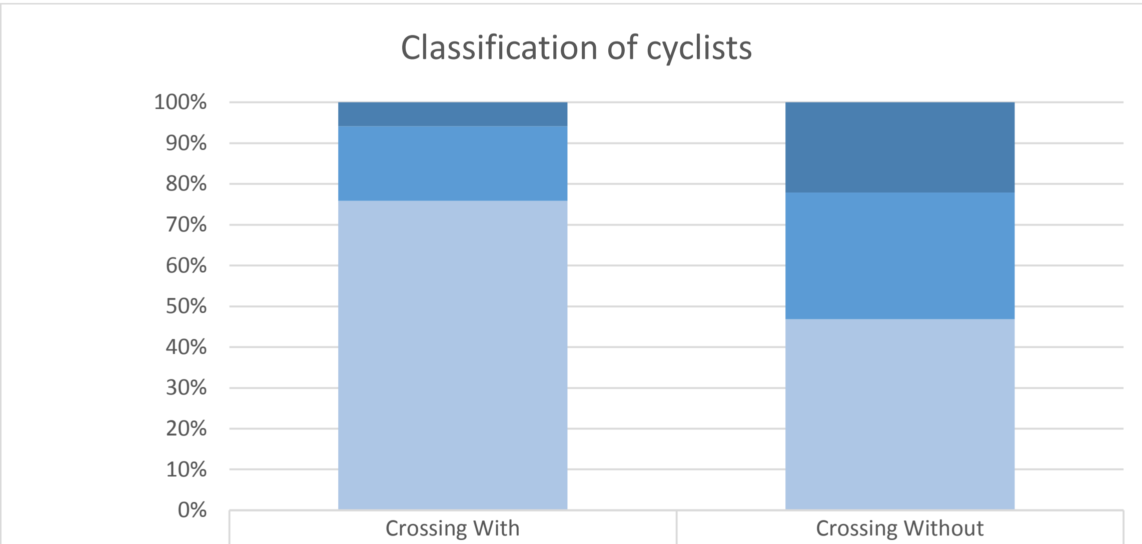
The second factor is the severity of the conflicts. The severity is classified according to the DOCTOR method plus the extra conflict class (0). The descriptions of the classes can be found in the methodology. For both crossings there were no conflicts of severity 4 or 5. In 80% of the conflicts at Crossing With the cyclist(s) who had priority could pass the crossing without having to brake or swerve. For Crossing Without this number is only 47%.



	Crossing With	Crossing Without
3	5	20
2	16	22
1	20	49
0	163	67

Figure 15: Conflict severity

In figure 16 the results for the third factor are shown, which is the classification of the cyclists who needed to give priority. The graphs show that at 75% of the conflicts at Crossing With the cyclists acted according to the rules and caused no dangerous situations. For Crossing Without this is 47% of the cyclists. A momentumist was part of a conflict in 18% for Crossing With and 31% for Crossing Without. And in 6% of the conflicts at Crossing With there was a recklist, who ignored the rules and thereby caused a dangerous situation. For Crossing Without this 22% of the conflicts.



	Crossing With	Crossing Without
Recklists	12	35
Momentumists	37	49
Conformists	154	74

Figure 16: Classification of cyclists who needed to give priority

The first factor that was addressed is the priority behaviour of cyclists. That factor can give an indication of the influence of priority markings. Priority is given at 90% of the conflicts at Crossing With and at 61% of the conflicts at Crossing Without. This would indicate that the priority rule, right has priority, is generally more ignored than the priority markings on the road. The statistical test confirms this difference in priority behaviour at the crossings. The result also show cyclists who have to give priority are more reckless and more severe conflicts occur at Crossing Without. This also indicates that cyclists are generally less likely to follow the priority rules at that crossing. There is however a difference in intensity of cyclists, which can result in more conflicts of cyclists from more than 2 directions and therefore causes higher alertness of cyclists. Also the riding directions that were observed are different. At Crossing Without the most observed conflicts were between left turning cyclists with priority and straight-ahead riding cyclists. This is the other way around for Crossing With, where the straight-ahead traffic had priority. This differences also influence the priority behaviour.

4.2 Scooters

Scooters have a higher speed than cyclists. Therefore conflicts including a scooter are discussed to see if scooters have an impact on the priority behaviour.

From the total number of 362 conflicts, only 37 conflicts involved a scooter. From those 37 conflicts the number of times priority was given and not given when it should be given were also determined. Those results are shown in table 1 and figure 17.

	Priority given	Priority not given while it should be given	Total
Scooter	26	11	37
No scooter	254	71	325
Total	280	82	362

Table 1: Priority behaviour with and without scooters

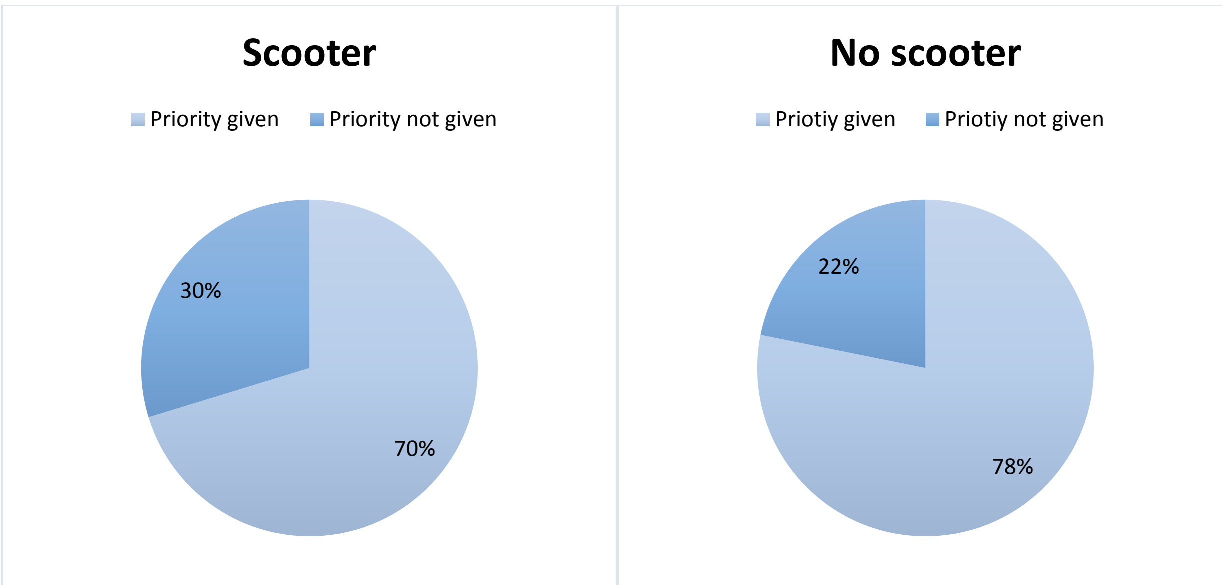


Figure 17: Priority behaviour with and without scooters

With the results for scooters a statistical test is performed to investigate the influence of scooters at crossings. Because there are two variables with two categories the chi-squared test can be used again. The variables are the two crossings and conflicts with or without scooters. The null hypothesis is: scooters do not change the priority behaviour at crossings. For the results of table 1 a chi-squared value of 1.180 is calculated, which is lower than the significance level of 3.841. Therefore the null hypothesis can be accepted, which indicates that scooters do not influence the priority behaviour. The calculations of the statistical test are shown in Appendix B.

The results show a higher percentage of conflicts in which priority was not given while it should be given. The statistical test however determined there is no relation between scooters and priority behaviour at crossings.

4.3 Groups

In this paragraph it is discussed if riding in groups results in different behaviour of cyclists. A hypothesis is tested with the results of the observations. The hypothesis is: A group is less likely to give priority when an individual cyclists is coming from the other direction.

The conflicts are divided into four classes which is shown in table 3. The first one is a conflict between two individualists. The second class is a conflict between an individual and a group, where the individual has priority. The third class also represents a conflict between an individual and a group, but here the group has priority. And the last group is a conflict between two groups. Groups represent two or more cyclists coming from the same direction.
In figure 18 the results for all four classes are shown.

	Priority given	**Priority not given while it should be**	**Total**
Individual - individual	146	31	177
Individual - group	46	18	64
Group - individual	62	21	83
Group - group	26	12	38
Total	280	82	362

Table 2: Conflicts with groups at Crossing With

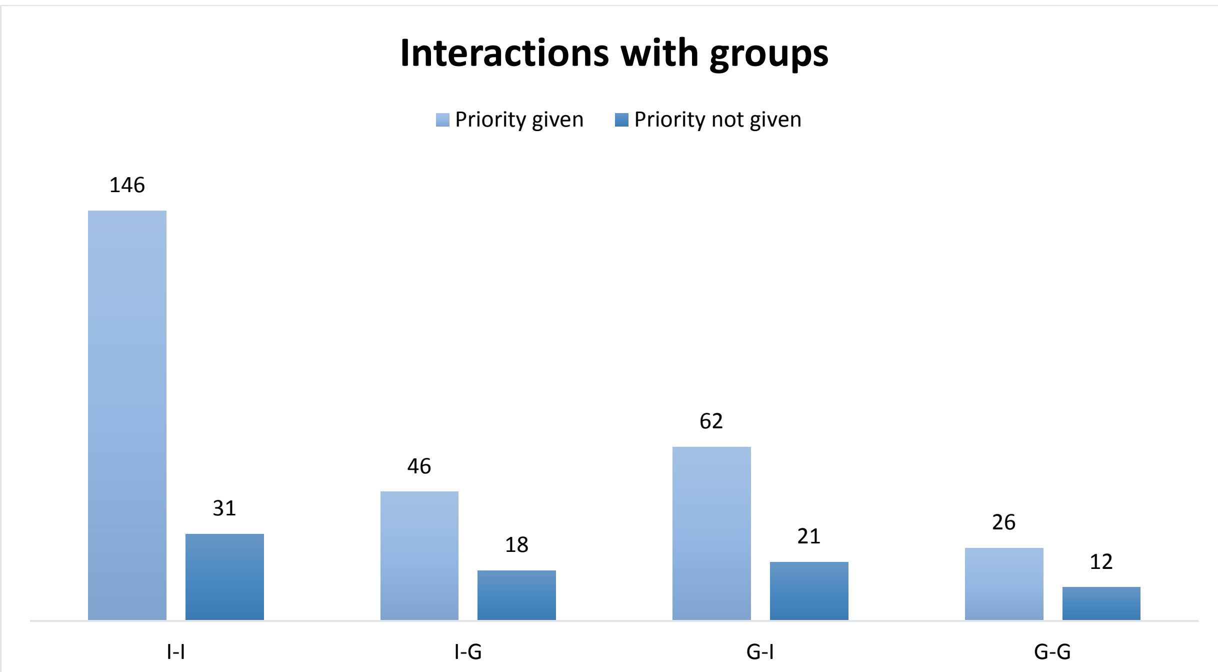


Figure 18: Conflicts with groups at Crossing With

The percentages of the times priority was not given while it should be given for all conflicts are 21% for I-I, 39% for I-G, 34% for G-I and 46% for G-G. With these percentages we can reject the hypothesis mentioned above. So groups are not less likely to give priority when an individual cyclists comes from the other direction. There is however a difference between conflicts with individuals (I-I) and conflicts with groups in general (I-G, G-I and G-G). The relation between priority behaviour and the presence of a group in a conflict is tested with the chi-squared test. The null hypothesis is in this case: Presence of groups in a conflict does not affect the priority behaviour of the cyclists. The chi-squared value calculated with the data from table 3 is 5.214. This is higher than the significance value 3.841 and therefore the null hypothesis can be rejected. So in conflicts with groups (I-G, G-I and G-G) priority is less likely to be given when it should be given. The calculations of the statistical test are shown in Appendix B.

4.4 Crossing or merging

There are two kinds of conflicts between cyclists on a crossing. The first kind is a conflict where cyclists come from two different directions and go in different directions while their paths cross. The second kind of conflict involves cyclists coming from different directions and merging on the crossing towards the same direction. This paragraphs investigates a possible difference in priority behaviour between the two kinds of conflicts.

The number of times priority is given and not given while it should be given are obtained from the data for both crossings. The results for Crossing With are shown in table 5 and figure 19.

	Priority given	Priority not given while it should be given	Total
Crossing	242	74	316
Merging	38	8	46
Total	280	82	362

Table 3: Crossing and merging conflicts

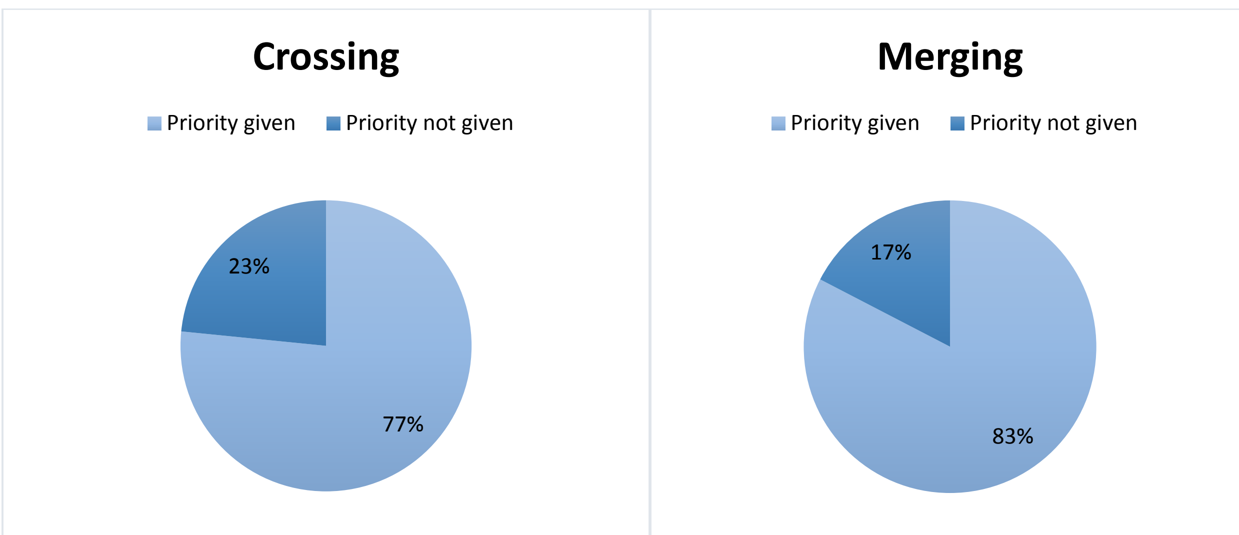


Figure 19: Crossing and merging conflicts

The chi-square test is performed to investigate a possible relation between the kind of conflict and the priority behaviour at the crossing. The null hypothesis is: there is no relation between the kind of conflict and the priority behaviour. The chi-squared value which is calculated with the results from table 5 is 0.362. This is lower than the significance value of 3.841, so the null hypothesis can be accepted. A merging or crossing conflict has no influence on the number of times priority is not given while it should be given. The calculations of the statistical test are shown in Appendix B.

4.5 Extra comments

At Crossing With 2 times a cyclist braked while he or she had priority. At Crossing Without this happened once. In these three conflicts priority was not given while it should have been given, because the cyclist who had priority was being very careful. Because the analysis classified both the cyclists who have priority and the cyclist who have to give priority, the conflicts do not need any further attention. Also at Crossing With one cyclist drove relatively slow while having priority, which does not need further attention either for the same reason. The last remarkable situation was at Crossing Without. At 8:26 there was a constant flow of cyclists coming from direction 1 in figure 12 for 8 minutes. It caused 7 conflicts in which priority was not given while it should have been given. These conflicts occurred because cyclists tried to get through the flow of cyclists. Some did this directly and others after stopping and waiting first. For the last case two conflicts are registered; one conflict in which priority was given and one conflict in which it was not while it should have been given.

5. Conclusions and Recommendations

All the results are discussed in the previous chapter. So conclusions can now be drawn with respect to the results and the hypotheses that were created before the observations. Also the research question will be answered. The research question is: *What is the influence of road markings on priority behaviour of cyclists where bicycle streets cross?* Finally recommendations can be given for further research into priority behaviour at bicycle crossings.

At the start of the research it was hypothesised that priority markings have a bigger influence on priority behaviour than the rule: traffic coming from the right has priority. A crossing without priority markings would in that case experience more severe conflicts. With the results from the observations and the statistical analysis both expectations can be confirmed. However, the priority markings and the priority rule are not the only factors that influence the priority behaviour. The intensity of the cyclists, the speed of the cyclists, the riding directions, objects near the crossing, size of the crossing and a slope in the road are all factors that could impact the cyclist's behaviour as well. So the research question can be answered by concluding that the priority markings have a positive influence on priority behaviour at bicycle street crossings. Therefore cyclists are more likely to follow the priority rules when priority markings control the priority on a crossing. It is however still unknown how much influence these markings have.

For three factors (groups, scooters and crossing/merging conflicts) the influence on priority behaviour is investigated. Scooters could influence priority behaviour in a negative way because of their higher speed. Priority behaviour is here defined as the number of times priority is given or not given while it should have been given. The results however show no relation between conflicts with scooters and conflicts without scooters regarding priority behaviour. This is also the case for the difference between crossing and merging conflicts. So the crossing and merging conflicts show no difference in priority behaviour. For groups it was hypothesised that they would be less likely to give priority to individuals in conflicts. But results show that this is not the case. Groups in general however are more likely to be part of conflicts where priority was not given while it should have been given.

The goal of this research is to gain knowledge about the influence of priority markings. It is concluded that they have an influence but not how much influence, so that could be investigated in further research. A similar research with observations of two crossings can be conducted, but in which all other influencing factors for both crossings should be analysed as well. Or two situations at the same crossing can be compared; one in which there are priority markings and a second situation in which the priority markings are removed. Finally it can be investigated why cyclists are less likely to obey the priority rules when they ride in groups.

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Appendix A

Crossing With

Crossing 1	Time	Cr/Me	BS/BB/SS	II/IG/GI/GG	Priority given	Conflict severity	C/M/R	Extra comment	
	8:04	Cr	BB	II	Y	0	C		Cr = Crossing
	8:04	Cr	BB	IG	Y	2	M		Me = Merging
	8:06	Me	BB	II	Y	0	C		
	8:13	Cr	BB	IG	Y	0	C		B = Bicycle
	8:14	Cr	BB	II	Y	0	C		S = Scooter
	8:15	Cr	BB	II	Y	0	C		
	8:16	Me	BB	II	Y	0	C		I = Individual
	8:16	Cr	BB	II	Y	0	C		G = Group
	8:17	Cr	BB	II	Y	0	C		
	8:18	Cr	BB	GI	Y	0	C		Conflict severity = 0,1,2,3,4,5
	8:18	Me	BS	II	Y	0	C		
	8:18	Me	BB	II	Y	0	C		C = Conformists
	8:19	Me	BB	GI	Y	0	C		M = Momentumists
	8:22	Cr	BB	GG	Y	0	C		R = Recklists
	8:22	Cr	BB	IG	Y	0	C		
	8:22	Me	BB	II	Y	0	C		
	8:23	Cr	BB	II	N	3	R		
	8:23	Cr	BB	II	Y	0	C		
	8:23	Cr	BB	II	Y	0	M		
	8:23	Cr	BB	GG	Y	0	C		
	8:24	Cr	BB	II	Y	0	C		
	8:25	Cr	BB	II	Y	0	C		
	8:25	Cr	BB	II	Y	0	C		
	8:25	Cr	BS	IG	Y	0	M		
	8:26	Cr	BB	II	Y	0	C		
	8:26	Cr	BB	IG	Y	1	M		
	8:26	Cr	BB	IG	Y	0	M		
	8:26	Me	BB	II	Y	0	M		
	8:26	Cr	BB	GI	Y	2	M	riding slowely (has priority)	
	8:26	Cr	BB	GI	Y	0	C		
	8:26	Cr	BB	II	Y	0	C		
	8:28	Me	BB	II	Y	0	C		
	8:29	Cr	BB	II	Y	0	C		
	8:30	Cr	BS	GG	Y	1	C		
	8:30	Cr	BB	II	Y	0	C		
	8:31	Cr	BB	GG	Y	0	M		
	8:31	Cr	BB	GI	Y	0	M		
	8:31	Cr	BB	GG	Y	0	C		
	8:31	Me	BB	GG	Y	0	C		
	8:31	Cr	BB	GI	Y	0	C		
	8:31	Cr	BB	II	Y	0	C		
	8:32	Me	BB	GI	N	1	R		
	8:32	Cr	BB	IG	Y	0	C		
	8:32	Me	BB	IG	N	1	R		
	8:32	Cr	BB	II	Y	0	C		
	8:32	Cr	BB	II	Y	0	C		
	8:33	Cr	BB	II	Y	1	M		
	8:33	Cr	BB	GG	Y	0	C		
	8:33	Cr	BB	II	Y	0	C		
	8:34	Cr	BB	IG	Y	0	C		
	8:34	Cr	BB	II	Y	0	M		
	8:34	Cr	BB	IG	Y	2	M		
	8:34	Cr	BB	II	Y	0	C		
	8:34	Cr	BB	GI	Y	0	C		
	8:35	Me	BB	GG	Y	0	C		
	8:35	Me	BB	IG	Y	0	C		
	8:35	Cr	BB	GG	Y	0	C		
	8:35	Cr	BB	II	Y	0	C		
	8:35	Me	BB	II	Y	0	C		
	8:35	Me	BB	II	Y	0	C		
	8:35	Cr	BB	II	Y	0	C		
	8:35	Cr	BB	II	N	3			
	8:36	Cr	BB	II	Y	1	M		
	8:36	Me	BB	II	Y	0	M		
	8:36	Cr	BB	II	Y	2	R		
	8:36	Cr	BB	II	Y	0	C		
	8:36	Cr	BB	II	Y	0	C		
	8:37	Cr	BS	II	Y	0	C		

	8:37	Cr	BB	IG	N	2	R		
	8:37	Cr	BB	IG	N	2	R		
	8:37	Me	BB	II	Y	0	C		
	8:37	Cr	BB	II	Y	0	C		
	8:37	Cr	BB	II	Y	0	C		
	8:38	Cr	BB	II	Y	1	M		
	8:38	Cr	BB	II	Y	0	C		
	8:38	Cr	BB	GI	Y	0	C		
	8:38	Cr	BB	II	N	1	M		
	8:38	Me	BB	IG	Y	0	C		
	8:38	Cr	BB	GI	Y	0	C		
	8:39	Cr	BB	IG	Y	0	C		
	8:39	Me	BB	IG	Y	0	C		
	8:39	Me	BB	IG	Y	0	C		
	8:39	Cr	BB	IG	Y	0	C		
	8:40	Cr	BB	IG	Y	0	M		
	8:40	Me	BB	II	Y	1	M		
	8:40	Cr	BB	GI	Y	1	M		
	8:41	Me	BB	GG	Y	0	C		
	8:41	Cr	BS	IG	Y	0	M		
	8:41	Cr	BB	IG	Y	0	C		
	8:42	Cr	BB	IG	Y	1	C		
	8:42	Me	BS	GI	N	2	R		
	8:42	Cr	BB	GG	Y	0	C		
	8:42	Cr	BB	GG	Y	0	C		
	8:42	Cr	BB	GG	N	2	R		
	8:42	Cr	BB	IG	N	3	R		
	8:43	Cr	BB	II	Y	0	C		
	8:43	Cr	BB	II	Y	0	C		
	8:43	Me	BB	II	Y	0	C		
	8:43	Cr	BB	GG	Y	1	C		
	8:43	Cr	BB	II	Y	0	C		
	8:44	Cr	BB	GI	Y	1	M		
	8:44	Me	BB	GI	Y	0	C		
	8:44	Cr	BB	GG	Y	0	C		
	8:44	Cr	BB	IG	Y	2	M		
	8:44	Cr	BB	II	Y	0	M		
	8:45	Cr	BS	II	Y	0	C		
	8:45	Cr	BB	II	Y	0	C		
	8:47	Cr	BS	II	Y	2	M		
	8:49	Cr	BB	IG	Y	0	C		
	8:50	Me	BB	II	Y	0	C		
	8:50	Cr	BB	II	N	1	M		
	8:50	Cr	BB	II	Y	0	C		
	8:50	Cr	BB	II	Y	0	C		
	8:50	Cr	BB	IG	Y	0	C		
	8:51	Cr	BB	GG	Y	0	C		
	8:52	Cr	BB	II	Y	0	C		
	8:52	Cr	BS	II	N	1	R		
	8:53	Cr	BB	GG	N	2	R		
	8:53	Cr	BB	II	Y	0	C		
	8:53	Cr	BB	II	Y	0	C		
	8:53	Cr	BB	II	Y	0	C		
	8:53	Cr	BS	II	Y	0	C		
	8:53	Cr	BB	II	Y	0	C		
	8:53	Cr	BB	GI	N	1	M		
	8:54	Cr	BB	IG	Y	0	C		
	8:56	Cr	BB	II	Y	1	M		
	8:57	Cr	BB	II	Y	0	C		
	8:58	Me	BB	II	Y	0	C		
	9:00	Cr	BB	II	Y	0	C		
	10:04	Cr	BB	GI	Y	0	C		
	10:23	Cr	BB	II	Y	0	C		
	10:23	Cr	BB	II	Y	0	C		
	10:41	Cr	BB	GI	Y	0	C		
	10:41	Cr	BB	II	Y	0	C		
	10:43	Cr	BS	GI	Y	0	C		
	10:44	Cr	BB	II	N	3	M	Brakes but has priority	

	10:45	Cr	BB	II	Y	0	C		
	10:46	Cr	BB	II	Y	0	C		
	10:47	Me	BB	II	Y	0	C		
	10:48	Me	BB	GI	Y	0	C		
	10:52	Cr	BB	II	Y	0	C		
	10:56	Cr	BB	II	Y	0	C		
	10:57	Cr	BB	II	Y	0	C		
	17:02	Cr	BB	II	Y	0	C		
	17:02	Cr	BB	II	Y	0	C		
	17:03	Cr	BS	II	Y	0	C		
	17:05	Cr	BB	II	Y	0	C		
	17:05	Cr	BB	II	Y	0	C		
	17:07	Cr	BB	II	Y	0	C		
	17:08	Cr	BS	II	Y	0	C		
	17:08	Me	BB	IG	Y	0	C		
	17:09	Cr	BS	II	Y	0	C		
	17:10	Cr	BB	GI	Y	0	C		
	17:10	Me	BB	II	Y	0	C		
	17:10	Cr	BS	II	Y	1	M		
	17:11	Cr	BB	II	Y	0	C		
	17:12	Me	BB	GI	Y	0	C		
	17:13	Me	BB	II	N	2	M	Brakes but has priority	
	17:13	Cr	BB	II	Y	0	C		
	17:16	Cr	BB	II	Y	0	M		
	17:16	Cr	BB	IG	Y	0	C		
	17:17	Cr	BB	II	Y	0	C		
	17:18	Cr	BB	II	Y	0	C		
	17:18	Cr	BB	II	Y	0	C		
	17:19	Cr	BS	II	Y	0	C		
	17:19	Cr	BB	II	Y	3	R		
	17:20	Cr	BB	II	Y	0	C		
	17:21	Me	BS	GI	Y	0	C		
	17:24	Me	BB	II	Y	0	C		
	17:24	Cr	BB	IG	Y	0	C		
	17:25	Me	BS	II	N	2	M		
	17:26	Cr	BS	II	Y	0	C		
	17:26	Cr	BS	II	Y	0	C		
	17:41	Me	BB	GG	Y	0	C		
	17:41	Cr	BB	GI	Y	0	C		
	17:41	Cr	BB	II	Y	0	C		
	17:42	Cr	BB	II	Y	0	C		
	17:42	Me	BB	II	Y	0	C		
	17:42	Cr	BS	GI	Y	0	C		
	17:42	Cr	BS	II	N	2	M		
	17:42	Cr	BB	II	Y	0	C		
	17:43	Me	BB	II	N	2	M		
	17:43	Cr	BB	GG	Y	0	C		
	17:43	Me	BB	GI	Y	0	C		
	17:43	Cr	BB	II	Y	0	C		
	17:44	Cr	BB	II	Y	0	C		
	17:45	Cr	BB	II	Y	0	C		
	17:45	Me	BB	II	Y	0	C		
	17:45	Cr	BB	II	Y	0	C		
	17:45	Cr	BS	II	Y	0	C		
	17:46	Cr	BB	IG	Y	0	C		
	17:46	Me	BB	II	Y	0	C		
	17:47	Cr	BB	II	Y	1	M		
	17:48	Cr	BB	II	Y	0	C		
	17:48	Cr	BB	II	Y	0	C		
	17:49	Cr	BB	II	Y	0	C		
	17:50	Cr	BB	II	Y	0	C		
	17:51	Cr	BB	II	Y	2	M		
	17:51	Cr	BB	II	Y	0	C		
	17:52	Cr	BB	II	Y	0	C		
	17:53	Cr	BB	II	Y	0	C		
	17:54	Cr	BB	GI	N	1	M		
	17:54	Cr	BB	II	Y	0	C		
	17:55	Cr	BB	II	Y	0	C		

Crossing Without

Crossing 2	Time	Cr/Me	BS/BB/SS	II/IG/GI/GG	Priority given	Conflict severity	C/M/R	Comment (extra)	
	8:11	Cr	BB	II	Y	0	C		Cr = Crossing
	8:11	Cr	BB	GI	Y	0	C		Me = Merging
	8:11	Cr	BB	II	Y	2	R		
	8:12	Cr	BB	II	Y	0	M		B = Bicycle
	8:13	Cr	BB	IG	Y	0	C		S = Scooter
	8:13	Cr	BB	IG	Y	2	R		
	8:15	Cr	BB	II	Y	0	C		I = Individual
	8:15	Cr	BB	GI	Y	0	C		G = Group
	8:15	Cr	BS	II	N	1	M		
	8:16	Cr	BB	GI	N	3	R		Conflict severity = 0,1,2,3,4,5
	8:16	Cr	BB	GI	Y	0	C		
	8:16	Cr	BB	GI	Y	0	C		C = Conformists
	8:17	Cr	BB	GI	Y	2	R		M = Momentumists
	8:18	Cr	BB	GI	Y	0	C		R = Recklists
	8:18	Cr	BB	GG	N	3	R		
	8:19	Cr	BB	GI	Y	0	C		
	8:20	Cr	BB	IG	N	3	R		
	8:21	Cr	BB	II	N	3	R		
	8:26	Cr	BB	GI	Y	0	C		
	8:26	Cr	BB	GI	Y	3	R		
	8:26	Cr	BB	GI	N	3	R		
	8:26	Cr	BB	GI	N	3	R	Big flow	
	8:27	Cr	BB	GI	N	2	M	Big flow	
	8:27	Cr	BB	GI	N	2	R	Big flow	
	8:27	Cr	BB	GI	Y	1	M	Big flow	
	8:28	Cr	BB	GI	N	2	M	Big flow	
	8:29	Cr	BB	GI	N	3	R	Big flow	
	8:30	Cr	BB	GI	Y	0	C	Big flow	
	8:30	Cr	BB	GI	Y	0	C	Big flow	
	8:30	Cr	BS	GG	N	2	M	Big flow	
	8:33	Cr	BB	GI	Y	0	C	Big flow	
	8:33	Cr	BB	GI	N	2	M	Big flow	
	8:33	Cr	BB	GI	Y	0	C	Big flow	
	8:33	Cr	BB	GI	Y	2	M	Big flow	
	8:34	Cr	BB	GI	Y	0	C	Big flow	
	8:35	Cr	BB	GI	Y	0	C		
	8:36	Cr	BB	GI	N	2	M		
	8:36	Cr	BB	GI	N	3	R		
	8:36	Cr	BB	GI	N	2	M		
	8:38	Cr	BB	GI	Y	0	C		
	8:38	Cr	BB	II	Y	0	C		
	8:38	Cr	BB	II	N	2	M		
	8:39	Cr	BB	II	Y	0	C		
	8:39	Cr	BS	GI	Y	1	M		
	8:40	Cr	BB	GI	Y	0	C		
	8:40	Cr	BB	GI	Y	0	C		
	8:41	Cr	BB	II	N	2	R		
	8:41	Cr	BB	II	N	2	M		
	8:41	Cr	BB	II	Y	0	C		
	8:42	Cr	BB	GI	Y	1	M		
	8:42	Cr	BB	GI	Y	0	C		
	8:42	Cr	BB	GG	Y	0	C		
	8:42	Cr	BB	GI	N	3	R		
	8:43	Cr	BB	GI	Y	0	C		
	8:43	Cr	BB	II	N	2	R		
	8:43	Cr	BS	GI	N	2	R		
	8:44	Cr	BB	GI	Y	0	C		
	8:44	Cr	BB	GI	Y	0	C		
	8:44	Cr	BB	GI	Y	0	C		
	8:44	Cr	BS	II	N	2	R		
	8:45	Cr	BB	II	N	3	R		
	8:45	Cr	BB	IG	Y	1	M		
	8:46	Cr	BB	II	Y	0	C		

	8:46	Cr	BB	GG	Y	0	C		
	8:48	Cr	BB	GI	Y	0	C		
	8:49	Cr	BB	II	Y	2	M		
	8:51	Cr	BB	II	N	3	R		
	8:53	Cr	BB	II	N	2	R		
	8:55	Cr	BB	II	Y	2	M		
	8:58	Cr	BB	GI	N	1	M		
	8:58	Cr	BS	GI	N	2	M		
	8:59	Cr	BB	II	Y	1	M		
	10:06	Cr	BB	GI	Y	0	C		
	10:11	Cr	BB	II	N	2	R		
	10:15	Cr	BB	GG	N	2	R		
	10:15	Cr	BB	II	Y	1	C		
	10:19	Cr	BS	IG	Y	0	C		
	10:39	Cr	BB	IG	Y	1	M		
	10:40	Cr	BB	IG	N	3	R		
	10:41	Cr	BB	GI	Y	0	C		
	10:41	Cr	BB	GI	Y	0	C		
	10:41	Cr	BB	GI	Y	0	C		
	10:41	Cr	BB	GG	N	3	R		
	10:42	Cr	BB	II	Y	0	C		
	10:43	Cr	BB	II	Y	0	C		
	10:43	Cr	BB	II	Y	1	C		
	10:44	Cr	BB	GG	N	2	C	Brakes but has priority	
	10:45	Cr	BB	GI	Y	0	C		
	10:45	Cr	BS	GI	Y	0	C		
	10:46	Cr	BB	II	N	2	M		
	10:47	Cr	BB	GI	Y	0	C		
	10:49	Cr	BB	IG	Y	2	M		
	10:50	Cr	BB	II	Y	1	C		
	11:02	Cr	BB	II	N	2	R		
	17:00	Cr	BB	GI	Y	0	C		
	17:08	Cr	BB	GI	N	2	R		
	17:08	Cr	BB	GI	N	2	R		
	17:08	Cr	BB	GG	Y	0	C		
	17:10	Cr	BB	II	Y	1	M		
	17:12	Cr	BB	IG	N	3	R		
	17:15	Cr	BB	IG	Y	0	C		
	17:15	Cr	BS	IG	Y	0	M		
	17:23	Cr	BB	IG	N	3	R		
	17:23	Cr	BS	II	Y	0	C		
	17:25	Cr	BB	GG	Y	0	C		
	17:25	Cr	BB	GG	N	3	M		
	17:26	Cr	BB	II	N	3	M		
	17:27	Cr	BS	II	Y	0	C		
	17:28	Me	BB	II	N	2	M		
	17:30	Cr	BB	IG	N	2	M		
	17:30	Cr	BB	IG	N	2	M		
	17:31	Cr	BB	II	N	2	M		
	17:32	Cr	BB	GG	Y	0	C		
	17:32	Cr	BB	II	Y	0	C		
	17:33	Cr	BB	II	Y	1	C		
	17:33	Cr	BB	IG	N	2	M		
	17:33	Me	BB	GG	Y	0	C		
	17:34	Cr	BB	II	Y	3	R		
	17:34	Cr	BS	IG	N	2	M		
	17:35	Cr	BB	II	Y	0	M		
	17:35	Cr	BB	GG	N	2	M		
	17:35	Cr	BB	IG	Y	1	M		
	17:36	Cr	BB	IG	Y	0	C		
	17:36	Cr	BB	II	N	2	R		
	17:36	Cr	BB	GG	Y	0	C		

	17:36	Cr	BS	IG	Y	1	C		
	17:36	Cr	BB	IG	Y	3	R		
	17:38	Cr	BB	II	Y	0	C		
	17:38	Cr	BB	IG	Y	1	C		
	17:38	Me	BB	IG	N	2	M		
	17:38	Me	BB	IG	Y	0	C		
	17:38	Cr	BS	II	N	2	M		
	17:40	Cr	BB	GG	N	2	M		
	17:40	Cr	BB	GI	Y	0	C		
	17:41	Cr	BB	II	N	3	R		
	17:41	Cr	BB	IG	Y	0	C		
	17:41	Cr	BB	IG	Y	0	C		
	17:41	Cr	BB	GI	Y	0	C		
	17:41	Cr	BB	IG	Y	0	C		
	17:42	Cr	BB	GG	N	2	M		
	17:44	Cr	BB	II	Y	0	C		
	17:44	Cr	BB	IG	N	2	M		
	17:45	Cr	BB	GI	Y	2	M		
	17:46	Cr	BB	IG	N	2	M		
	17:50	Cr	BB	GI	Y	1	M		
	17:51	Cr	BB	II	Y	0	C		
	17:51	Cr	BB	II	Y	0	C		
	17:52	Cr	BB	GG	N	2	C		
	17:52	Cr	BB	II	N	3	R		
	17:52	Cr	BB	IG	Y	1	C		
	17:52	Cr	BB	IG	N	2	M		
	17:52	Cr	BB	GG	Y	0	C		
	17:55	Cr	BB	II	N	2	M		
	17:57	Cr	BB	GG	Y	1	M		
	17:57	Cr	BB	IG	Y	1	C		
	17:57	Cr	BB	IG	N	2	M		
	17:58	Cr	BB	IG	N	2	M		
	17:58	Cr	BB	II	Y	0	C		

Appendix B

```
import numpy as np
import matplotlib.pyplot as plt
%matplotlib inline
import pandas as pd
from pandas import read_csv
```

```
data_xls1 = pd.read_excel('Conflicts crossing with priority markings.xlsx')
data_xls1.to_csv('Conflicts crossing with priority markings.csv', encoding='utf-8')
data_xls2 = pd.read_excel('Conflicts crossing without priority markings.xlsx')
data_xls2.to_csv('Conflicts crossing without priority markings.csv', encoding='utf-8')

crossing1 = read_csv('Conflicts crossing with priority markings.csv')
crossing2 = read_csv('Conflicts crossing without priority markings.csv')
```

Conflict information

<u>Crossing With and Crossing Without (priority behaviour, classification of cyclists and conflict severity)</u>

```
: pd.value_counts(crossing1['Priority given'])
```

```
: Y    184
  N     20
  Name: Priority given, dtype: int64
```

```
: pd.value_counts(crossing2['Priority given'])
```

```
: Y    96
  N    62
  Name: Priority given, dtype: int64
```

```
: pd.value_counts(crossing1['C/M/R'])
```

```
: C    154
  M     37
  R     12
  Name: C/M/R, dtype: int64
```

```
: pd.value_counts(crossing2['C/M/R'])
```

```
: C    74
  M    49
  R    35
  Name: C/M/R, dtype: int64
```

```
: pd.value_counts(crossing1['Conflict severity'])
```

```
: 0.0    163
  1.0     20
  2.0     16
  3.0      5
  Name: Conflict severity, dtype: int64
```

```
: pd.value_counts(crossing2['Conflict severity'])
```

```
: 0.0    67
  2.0    49
  3.0    22
  1.0    20
  Name: Conflict severity, dtype: int64
```

Crossing With (groups)

```
IIY = 0
IIN = 0
IGY = 0
IGN = 0
GIY = 0
GIN = 0
GGY = 0
GGN = 0

for i in range(len(crossing1)):
    if crossing1.iloc[i,5] == 'II' and crossing1.iloc[i,6] == 'Y':
        IIY += 1
    elif crossing1.iloc[i,5] == 'II' and crossing1.iloc[i,6] == 'N':
        IIN += 1
print IIY, 'times priority given when two individuals interact'
print IIN, 'times priority not given when two individuals interact'

for i in range(len(crossing1)):
    if crossing1.iloc[i,5] == 'IG' and crossing1.iloc[i,6] == 'Y':
        IGY += 1
    elif crossing1.iloc[i,5] == 'IG' and crossing1.iloc[i,6] == 'N':
        IGN += 1
print IGY, 'times priority given when an individual has priority over a group'
print IGN, 'times priority not given when an individual has priority over a group'

for i in range(len(crossing1)):
    if crossing1.iloc[i,5] == 'GI' and crossing1.iloc[i,6] == 'Y':
        GIY += 1
    elif crossing1.iloc[i,5] == 'GI' and crossing1.iloc[i,6] == 'N':
        GIN += 1
print GIY, 'times priority given when a group has priority over an individual'
print GIN, 'times priority not given when a group has priority over an individual'

for i in range(len(crossing1)):
    if crossing1.iloc[i,5] == 'GG' and crossing1.iloc[i,6] == 'Y':
        GGY += 1
    elif crossing1.iloc[i,5] == 'GG' and crossing1.iloc[i,6] == 'N':
        GGN += 1
print GGY, 'times priority given when two groups interact'
print GGN, 'times priority not given when two groups interact'
```

```
118 times priority given when two individuals interact
10 times priority not given when two individuals interact
27 times priority given when an individual has priority over a group
4 times priority not given when an individual has priority over a group
22 times priority given when a group has priority over an individual
4 times priority not given when a group has priority over an individual
17 times priority given when two groups interact
2 times priority not given when two groups interact
```

Crossing Without (groups)

```
IIY = 0
IIN = 0
IGY = 0
IGN = 0
GIY = 0
GIN = 0
GGY = 0
GGN = 0

for i in range(len(crossing2)):
    if crossing2.iloc[i,5] == 'II' and crossing2.iloc[i,6] == 'Y':
        IIY += 1
    elif crossing2.iloc[i,5] == 'II' and crossing2.iloc[i,6] == 'N':
        IIN += 1
print IIY, 'times priority given when two individuals interact'
print IIN, 'times priority not given when two individuals interact'

for i in range(len(crossing2)):
    if crossing2.iloc[i,5] == 'IG' and crossing2.iloc[i,6] == 'Y':
        IGY += 1
    elif crossing2.iloc[i,5] == 'IG' and crossing2.iloc[i,6] == 'N':
        IGN += 1
print IGY, 'times priority given when an individual has priority over a group'
print IGN, 'times priority not given when an individual has priority over a group'

for i in range(len(crossing2)):
    if crossing2.iloc[i,5] == 'GI' and crossing2.iloc[i,6] == 'Y':
        GIY += 1
    elif crossing2.iloc[i,5] == 'GI' and crossing2.iloc[i,6] == 'N':
        GIN += 1
print GIY, 'times priority given when a group has priority over an individual'
print GIN, 'times priority not given when a group has priority over an individual'

for i in range(len(crossing2)):
    if crossing2.iloc[i,5] == 'GG' and crossing2.iloc[i,6] == 'Y':
        GGY += 1
    elif crossing2.iloc[i,5] == 'GG' and crossing2.iloc[i,6] == 'N':
        GGN += 1
print GGY, 'times priority given when two groups interact'
print GGN, 'times priority not given when two groups interact'
```

```
28 times priority given when two individuals interact
21 times priority not given when two individuals interact
19 times priority given when an individual has priority over a group
14 times priority not given when an individual has priority over a group
40 times priority given when a group has priority over an individual
17 times priority not given when a group has priority over an individual
9 times priority given when two groups interact
10 times priority not given when two groups interact
```

Crossing With (scooters)

```
BSY = 0
BSN = 0
for i in range(len(crossing1)):
    if crossing1.iloc[i,4] == 'BS' and crossing1.iloc[i,6] == 'Y':
        BSY += 1
    elif crossing1.iloc[i,4] == 'BS' and crossing1.iloc[i,6] == 'N':
        BSN += 1
print BSY, 'times priority given when a scooter is involved'
print BSN, 'times priority not given when a scooter is involved'

BBY = 0
BBN = 0
for i in range(len(crossing1)):
    if crossing1.iloc[i,4] == 'BB' and crossing1.iloc[i,6] == 'Y':
        BBY += 1
    elif crossing1.iloc[i,4] == 'BB' and crossing1.iloc[i,6] == 'N':
        BBN += 1
print BBY, 'times priority given when no scooter is involved'
print BBN, 'times priority not given when no scooter is involved'
```

```
19 times priority given when a scooter is involved
4 times priority not given when a scooter is involved
165 times priority given when no scooter is involved
16 times priority not given when no scooter is involved
```

Crossing Without (scooters)

```
BSY = 0
BSN = 0
for i in range(len(crossing2)):
    if crossing2.iloc[i,4] == 'BS' and crossing2.iloc[i,6] == 'Y':
        BSY += 1
    elif crossing2.iloc[i,4] == 'BS' and crossing2.iloc[i,6] == 'N':
        BSN += 1
print BSY, 'times priority given when a scooter is involved'
print BSN, 'times priority not given when a scooter is involved'

BBY = 0
BBN = 0
for i in range(len(crossing2)):
    if crossing2.iloc[i,4] == 'BB' and crossing2.iloc[i,6] == 'Y':
        BBY += 1
    elif crossing2.iloc[i,4] == 'BB' and crossing2.iloc[i,6] == 'N':
        BBN += 1
print BBY, 'times priority given when no scooter is involved'
print BBN, 'times priority not given when no scooter is involved'
```

```
7 times priority given when a scooter is involved
7 times priority not given when a scooter is involved
89 times priority given when no scooter is involved
55 times priority not given when no scooter is involved
```

Crossing With and Crossing Without (crossing/merging)

```
MeY = 0
MeN = 0
for i in range(len(crossing1)):
    if crossing1.iloc[i,3] == 'Me' and crossing1.iloc[i,6] == 'Y':
        MeY += 1
    elif crossing1.iloc[i,3] == 'Me' and crossing1.iloc[i,6] == 'N':
        MeN += 1
print MeY, 'times priority given when the cyclists merged'
print MeN, 'times priority not given when the cyclists merged'

CrY = 0
CrN = 0
for i in range(len(crossing1)):
    if crossing1.iloc[i,3] == 'Cr' and crossing1.iloc[i,6] == 'Y':
        CrY += 1
    elif crossing1.iloc[i,3] == 'Cr' and crossing1.iloc[i,6] == 'N':
        CrN += 1
print CrY, 'times priority given when the cyclists crossed'
print CrN, 'times priority not given when the cyclists crossed'
```

```
36 times priority given when the cyclists merged
6 times priority not given when the cyclists merged
148 times priority given when the cyclists crossed
14 times priority not given when the cyclists crossed
```

```
MeY = 0
MeN = 0
for i in range(len(crossing2)):
    if crossing2.iloc[i,3] == 'Me' and crossing2.iloc[i,6] == 'Y':
        MeY += 1
    elif crossing2.iloc[i,3] == 'Me' and crossing2.iloc[i,6] == 'N':
        MeN += 1
print MeY, 'times priority given when the cyclists merged'
print MeN, 'times priority not given when the cyclists merged'

CrY = 0
CrN = 0
for i in range(len(crossing2)):
    if crossing2.iloc[i,3] == 'Cr' and crossing2.iloc[i,6] == 'Y':
        CrY += 1
    elif crossing2.iloc[i,3] == 'Cr' and crossing2.iloc[i,6] == 'N':
        CrN += 1
print CrY, 'times priority given when the cyclists crossed'
print CrN, 'times priority not given when the cyclists crossed'
```

```
2 times priority given when the cyclists merged
2 times priority not given when the cyclists merged
94 times priority given when the cyclists crossed
60 times priority not given when the cyclists crossed
```

Intensity of the conflicts

<u>Crossing Without</u>

```
c1 = np.loadtxt('Aantal_fietsers_crossing_with.txt',dtype=object)
count1 = 0
count2 = 0
count3 = 0
count4 = 0
for i in range(len(c1)):
    if c1[i,2] == '1':
        count1 += 1
    if c1[i,2] == '2':
        count2 += 1
    if c1[i,2] == '3':
        count3 += 1
    if c1[i,2] == '4':
        count4 += 1
print count1, 'cyclists from direction 4'
print count2, 'cyclists from direction 2'
print count3, 'cyclists from direction 3'
print count4, 'cyclists from direction 1'
```

```
152 cyclists from direction 4
60 cyclists from direction 2
14 cyclists from direction 3
70 cyclists from direction 1
```

<u>Crossing Without</u>

```
c2 = np.loadtxt('Aantal_fietsers_crossing_without.txt',dtype=object)
count_1 = 0
count_2 = 0
count_3 = 0
count_4 = 0
count_5 = 0

for i in range(len(c2)):
    if c2[i,2] == '1':
        count_1 += 1
    if c2[i,2] == '2':
        count_2 += 1
    if c2[i,2] == '3':
        count_3 += 1
    if c2[i,2] == '4':
        count_4 += 1
    if c2[i,2] == '5':
        count_5 += 1
print count_1, 'cyclists from direction 2 turning right'
print count_2, 'cyclists from direction 2 going straight or turning left'
print count_3, 'cyclists from direction 1'
print count_4, 'cyclists from direction 4'
print count_5, 'cyclists from direction 3'
```

```
57 cyclists from direction 2 turning right
50 cyclists from direction 2 going straight or turning left
396 cyclists from direction 1
266 cyclists from direction 4
24 cyclists from direction 3
```

Appendix C

A statistical test is performed on the results of the observations. The calculations of the chi-squared test are given below. In the chi-squared test two variables with both two categories are used as input. The null-hypothesis is that the two variables are independent. The combinations of all categories gives four possible observations, which are shown in the table below as $O_{i,j}$. These represent the number of times an observations happened.

Observations	Variable 1 Category 1	Variable 1 Category 2	Total
Variable 2 Category 1	$O_{1,1}$	$O_{1,2}$	$\sum O_{1,j}$
Variable 2 Category 2	$O_{2,1}$	$O_{2,2}$	$\sum O_{2,j}$
Total	$\sum O_{i,1}$	$\sum O_{i,2}$	N

N = number of observations = 362

$O_{i,j}$ = number of observations

p = the fraction of observations of type i or j

E = the expected number based on the observations per category and the total number of observations.

The following formulas are used to calculate the expected number of observations:

$$p_i = \frac{\sum O_i}{N}$$

$$p_j = \frac{\sum O_j}{N}$$

$$E_{i,j} = N p_i p_j$$

The expectations are shown in the table below. There should be a minimum of 5 expectations in every cell in the table. If the number is less for any expectation, the result of the test is not sufficient to determine (in)dependence of variables.

Expectations	Variable 1 Category 1	Variable 1 Category 2	Total
Variable 2 Category 1	$E_{1,1}$	$E_{1,2}$	$\sum E_{1,j}$
Variable 2 Category 2	$E_{2,1}$	$E_{2,2}$	$\sum E_{2,j}$
Total	$\sum E_{i,1}$	$\sum E_{i,2}$	N

The chi-squared value can be calculated with the following formula:

$$X^2 = \sum_{i=1}^{r} \sum_{j=1}^{c} \frac{(O_{i,j} - E_{i,j})^2}{E_{i,j}}$$

The decree of freedom (DF) is determined by the formula: (Rows-1)*(Columns-1), in which ''Rows'' is the number of categories of the first variable and ''Columns'' is the number of categories of the second variable.

If X^2 is 0 there will be no difference between the observations and expectations, so the null hypothesis can be accepted. The significance level is set at a probability of 0.05 (5%) that the null hypothesis is correct. For 1 DF this corresponds with a chi-squared value of 3.841 (Heijnen, 2008). So if the calculated chi-squared value is higher than 3.841, the null hypothesis is rejected.

Priority behaviour and priority markings

The table below shows the data from the observations.

Observations	Priority given	Priority not given	Total
Crossing With	184	20	204
Crossing Without	96	62	158
Total	280	82	362

The expectations are shown in the table below.

Expectations	Priority given	Priority not given	Total
Crossing With	157.79	46.21	204
Crossing Without	122.21	35.79	158
Total	280	82	362

The chi-squared value can be calculated with the following formula:

$$X^2 = \sum_{i=1}^{r}\sum_{j=1}^{c}\frac{(O_{i,j}-E_{i,j})^2}{E_{i,j}}$$

$$X^2 = \frac{(184-157.79)^2}{157.79}+\frac{(20-46.21)^2}{46.21}+\frac{(96-122.21)^2}{122.21}+\frac{(62-35.79)^2}{35.79} = 44.035$$

DF = (Rows - 1) * (Columns - 1) = 1

$X^2 > 3.841$

The null hypotheses H0 can be rejected.

Scooters and priority behaviour

The table below shows the data from the observations.

Observations	Priority given	Priority not given	Total
Scooters	26	11	37
No scooters	254	71	325
Total	280	82	362

The expectations are shown in the table below.

Expectations	Priority given	Priority not given	Total
Scooters	28.62	8.38	37
No scooters	251.38	73.62	325
Total	280	82	362

$$X^2 = \sum_{i=1}^{r}\sum_{j=1}^{c}\frac{(O_{i,j}-E_{i,j})^2}{E_{i,j}}$$

$$X^2 = \frac{(26-28.62)^2}{28.62}+\frac{(11-8.38)^2}{8.38}+\frac{(254-251.38)^2}{251.38}+\frac{(71-73.62)^2}{73.62} = 1.180$$

DF = (Rows - 1) * (Columns - 1) = 1

$X^2 < 3.841$

The null hypotheses H0 can be accepted.

Groups and priority behaviour

The table below shows the data from the observations.

Observations	Priority given	Priority not given	Total
Group	146	31	177
No group	134	51	185
Total	280	82	362

The expectations are shown in the table below.

Expectations	Priority given	Priority not given	Total
Group	136.91	40.09	177
No group	143.09	41.91	185
Total	280	82	362

$$X^2 = \sum_{i=1}^{r}\sum_{j=1}^{c}\frac{(O_{i,j} - E_{i,j})^2}{E_{i,j}}$$

$$X^2 = \frac{(146 - 136.91)^2}{136.91} + \frac{(31 - 40.09)^2}{40.09} + \frac{(134 - 143.09)^2}{143.09} + \frac{(51 - 41.91)^2}{41.91} = 5.214$$

DF = (Rows - 1) * (Columns - 1) = 1

$X^2 > 3.841$

The null hypotheses H0 can be rejected.

Priority behaviour and type of conflict

The table below shows the data from the observations.

Observations	Priority given	Priority not given	Total
Group	242	74	316
No group	38	8	46
Total	280	82	362

The expectations are shown in the table below.

Expectations	Priority given	Priority not given	Total
Group	244.42	71.58	316
No group	35.58	10.42	46
Total	280	82	362

$$X^2 = \sum_{i=1}^{r}\sum_{j=1}^{c}\frac{(O_{i,j} - E_{i,j})^2}{E_{i,j}}$$

$$X^2 = \frac{(242 - 244.42)^2}{244.42} + \frac{(74 - 71.58)^2}{71.58} + \frac{(38 - 35.58)^2}{35.58} + \frac{(8 - 10.42)^2}{10.42} = 0.832$$

DF = (Rows - 1) * (Columns - 1) = 1

$X^2 < 3.841$

The null hypotheses H0 can be accepted.