Assessment of methods to calculate modal split for the municipality of Enschede

BSc-thesis CE

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1 Preface

This is the report on my bachelor thesis 'Assessment of methods to calculate modal split for the municipality of Enschede'. The project, that was in collaboration with the municipality of Enschede, showed me what it is like working for a governmental institution, even though I had to work from home the majority of the time due to Covid-19. Besides the change in work environment the project learned me what it is like doing research on my own, and taught me to think outside of the box when things do not go as planned.

I would like to express a special thanks to both my supervisors Benjamin Groenewolt (municipality of Enschede) & Tom Thomas (University of Twente). Their patience and flexibility with regards to delays in the project, and there help getting the project back on the rails when it did not go entirely to the proposed plan helped bring this project to an end. Furthermore I would like to thank Mobidot for sharing the data that was required to get the project to where it is now. Moreover I would like to thank Johan Koolwaaij (Mobidot) for taking the time to prepare and help me understand the data.

Hotse Buursma
Enschede, July 26, 2021

2 Abstract

In this study an assessment of different methods to calculate modal split is conducted for the municipality of Enschede. The methods are assessed based on how well they meet the municipalities requirements and wishes. Additionally two criteria, costs & sample-size are added to the assessment to establish the performance of each method. In the study five different methods are assessed: survey based, smartphone tracking, Ovia, FietsViewer and WiFi/Bluetooth trackers. To determine the best method for the municipality of Enschede three steps are taken.

First, the requirements and wishes of the municipality were established through the means of desk research. The desk research consisting of research into the goals from the mobility and bike vision, and how they relate to the usage of modal split within the municipality. Additionally meetings with experts were held to better establish the municipalities needs from modal split, and gain a more comprehensive set of criteria.

Second, was the assessment of the methods on the established requirements, the assessment was conducted using literature on each of the included methods. Additionally criteria costs and sample size were added to the assessment to get a better insight on the performance of each method. From the assessment it was concluded that smartphone tracking is for the municipality the most suitable method to calculate modal split. It met all the necessary requirements and scored better on the additional criteria than the other methods. Cheaper than Ovia and bigger estimated sample-size.

Third, a closer look is taken to the possible way to implement smartphone tracking in the municipality. One possibility being the use of Fietstad Enschede app as source of data. A dataset consisting of trips registered by the app between the beginning of June 2020 and the end of May 2021 is used to calculate modal split. A comparison is made with results of the research program Odin to show the disadvantages of using the Fietstad Enschede app. The enormous disadvantage being a bias created in the sample by the design of the app. To counter this bias solutions are proposed in this project. The first cleaning the data of round trips (trips with the same start and end location), as these trips are most commonly made on the bike by fanatic cyclists. However this did not lead to the hoped effect and thus another solution is proposed. The second solution is additional recruitment using payment as reward for participating, thus making it more attractive to the general populace and counter the bias. Moreover to properly counter the bias it is necessary to create a sample separate from the already existing users of the app. For the system of payment to function and keep the costs low an optimal measuring period of the year is established.

Conclusion smartphone tracking has the most potential and is most suitable method to calculate modal split. The method can be implemented in two ways; using Fietstad Enschede or NVP (nationaal verplaatsingspanel). Fietstad Enschede has a disadvantage in the form of a bias in the sample, and NVP has the disadvantage of low sample-size. Both can be solved by additional recruitment using a payment system. However as NVP uses an app that does not favor a particular group of people, the advice would be to use NVP.

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3 Introduction

3.1 Problem description

In the 2020 bike vision (Fietsvisie) of the municipality of Enschede, a number of goals has been set. The main goal of the 2020 vision was to significantly increase bike usage in the future, and will thus continue beyond the year 2020, especially for trips up to 7.5km. To measure the progress of this goal the municipality required insight in the share of trips made on the bike in their area. This is achieved by using results of a national research into modal split called Odin. Modal split is the division of mobility modes used for trips, which includes share of trips made on the bike.

However the municipality is considering an alternative measuring method for the modal split. The main reason for this is that another option has presented itself in the form of app-data. The bike app implemented in the region of the municipality has the purpose of getting more people on the bike (Enschede fietstad, nd). While doing this it collects data about the trips the users of the app make, which could be the basis for calculating the modal split.

The reason that the municipality sees the app-data as an alternative or even better option, is the sample size from which the modal split is calculated. The Ovin research on a national level has 37016 respondents on a population of 16.48 million (CBS, nd), this translates to 0.22%. If we were to apply this percentage on the population of the municipality of Enschede 159734 in 2020 (AlleCijfers.nl, nd), it would result in a number of 351 respondents in a year. Compare this to 1146 users of the bike app (Empower, nd), which would triple the sample size, and you can see the potential.

To illustrate the problem of the current system (Ovin) a look should be taken at an study conducted in Canada. The study researched sample sizes in travel surveys (Nurul Habib, Khandker and El-Assi, Wafic, 2016), they gain a results that states a sample size of 5%, that is achieved in parts of Canada, has an 80% or higher accuracy. Then comparing this to the 0.22% sample size reached in the Netherlands and the problem is put into perspective.

The possibility of using data collected by the bike app is an option where the municipality sees great promise. However they do want to cover more than just one possibility, to make sure that they do not miss out on an even better option.

3.2 Research Framework

3.2.1 Research objective

The research objective of this study is:

Establish what method the municipality of Enschede can best use to calculate modal split in their region.

The general aim of this study is to establish what method the municipality of Enschede can best be used to calculate modal split. In this study multiple existing methods are researched in order to achieve the aim. Besides establishing which method can best be used, a second aim of the study is to do research into implementation of this best methods and possible problems that accompany implementation of the method.

3.2.2 Scope

The scope of the project is the borders of the municipality of Enschede. Trips that occur outside of the borders have no effect on the modal split for the municipality of Enschede, therefore the scope can be limited to the borders of the municipality of Enschede.

3.2.3 Research questions

Three research questions are setup, from which the answers will guide the project to achieve its general aim.

The first research question focuses on establishing a set of requirements that a method should meet, so it generates useful results to the municipality if implemented.

1. What requirements, based of municipal policy, must a method meet?

The second research question is established to determine which methods are serious options as an alternative to Mon/Ovin/Odin for the municipality.

2. Based on the requirements which methods are viable options to implement in the municipality of Enschede?

The last research question is setup to gain insight in what is required to make the most suitable method work in the region of the municipality of Enschede.

3. What is required in order to make the most suitable option (best method to calculate modal split) function within the municipality of Enschede?

3.3 Literature

3.3.1 Different methods to calculate modal split

In this study different options to calculate modal split are explored for the municipality of Enschede. But what are these options, what is state-of-the-art with regards to calculating modal split? What are other policy-makers doing? Which innovations could become a new method to determine modal split? These questions are answered with help of literature, and the results are stated in this chapter.

Survey based
Starting with a method that was used decades ago but is still heavily relied upon when it comes to calculating modal split: survey-based. There are two current day research programs in the Netherlands that are survey-based:

Odin
The first being the national research program named Odin or onderweg in Nederland. It is the latest research program in line of national research programs starting in 1978 with OVG (Vervoerregio Amsterdam, 2018). However since 1978 much innovation has occurred within the national research program and in general with the survey-based method. With each new research program time and money was invested in modernizing the information collection system.

Currently the method sends invitations to randomly chosen inhabitants of the Netherlands, inviting them to fill in a single days worth of trips into an online questionnaire (CBS, 2019). Using that data modal split for the entire Netherlands can be calculated. The disadvantage of using odin is the low sample-size when zooming in on a smaller area (like a municipality) in the Netherlands. Moreover short-trips are greatly underestimated in Odin, as respondents either do not think they matter or just forget these trips (Tom Thomas, Karst Geurs, Marcel Bijlsma and Salima Douhou, 2014).

OVIA
The other being a municipal research program called Ovia or onderzoek verplaatsingen in Amsterdam. The main differences besides the size of the program is that OViA is only conducted in certain parts of the year, and is conducted every two years instead of one (Gemeente Amsterdam, 2019). The biggest disadvantage is the high costs to maintain a program like Ovia, which is the reason that it has not been replicated anywhere else.

As Ovia and Odin have big differences when it comes to calculating modal split, they will be considered as two separate options in the remainder of the study. The differences being that costs and sample-size are very different for both methods, and that Ovia allows for much more control by the municipality if a similar program was to be implemented.

Smartphone tracking
Next is a method that was only recently discovered and possible to implement: smartphone tracking. With the smartphone becoming an integrate part of life for the majority of people,

smartphone tracking not only becomes an option but might even be the future of determining modal split. Smartphone tracking uses functions of smartphones to track where users of a smartphone are going. For example google uses smartphone tracking for navigation function in google maps.

Most of this data is not stored and only used to personalize apps and functions on the smartphone. But in multiple studies (Tom Thomas, Karst Geurs, Marcel Bijlsma and Salima Douhou, 2014) & (Norbert Brändle, 2021) it is shown that with the right tools this data can be used to calculate modal split in an area. In both studies an app is used that automatically tracks the trips made with the use of GPS, Wifi, cell-ID, gyroscope, accelerometer, Magnetometer and pressure meter.

The advantage of smartphone tracking is the relative low costs compared to survey based. Moreover as almost everyone has a smartphone the number of people involved in a research can be massive. On the other hand the biggest issue is privacy, by constantly with what can only be called spying on users might scare of potential new users.

Induction loops

Besides the municipality of Amsterdam there is another municipality that gains insight in the traffic situation in there municipality. The municipality of Den Haag uses an open source application called FietsViewer, which uses data from induction loops planted in bike lanes near cross-sections. The data shows the amount of cyclists passing a cross-section giving insight in the usage of the bike mobility mode, but also determines waiting times for cross-sections that have traffic lights (Marjolein van Trigt, 2019).

The advantage is the low costs and the enormous amount of data that can be collected by this system. There is however a disadvantage to this method, as it only counts something passing an induction loop, a car or bike, but nothing more. Therefore allowing for potential double counts, a car passes induction loops on multiple occasions, counting as more trips than in reality occurred.

Bluetooth/Wifi trackers

Due to recent technological development the use of WiFi and Bluetooth has increased massively, not just at home but also when people travel. With the help of Bluetooth/WiFi trackers this WiFi/Bluetooth use can be exploited to gain insight in the traffic situation within regions.

An example of these Bluetooth/WiFi trackers is implemented in the harbor of Rotterdam (Hans Wolfrat, 2014), where they use Bluetooth function in electronic devices to detect traffic. Each time an electronic device, that has Bluetooth function turned on, passes a Bluetooth-box a registration of its unique ID is made. Then when it is again registered at another Bluetooth-box information on the trip the user of the electronic device makes is gained.

The disadvantage of Bluetooth/WiFi trackers is that it cannot accurately determine the mobility mode when Bluetooth signal is detected. The information gathered by the trackers does not give information on mobility mode. By cleverly placing the boxes, along railways or highways for example, it can be determined in some cases. However in general the trackers do not gain information on mobility mode therefore making it difficult to gain a accurate modal split from the method.

3.3.2 Weather influence on modal split

Something to take into account when calculating the modal split is the temporal variations in modal split. Two papers (Thomas, Tutamwebwa and Jaarsma, Rinus and Tutert, S.I.A., 2007) & (Petrovic, Ivanovic, Doric and Jovic, 2020) contribute large parts of temporal variation to weather conditions.

In figure 2 from (Thomas, Tutamwebwa and Jaarsma, Rinus and Tutert, S.I.A., 2007) the influence of weather on cycling is visualized, showing large differences even in a the same week. Similarly walking will experience impact of weather conditions, as with both types of mobility mode the user is exposed to the weather conditions. With two mobility modes fluctuating due to weather conditions, large differences even from day to day in modal split can be expected.

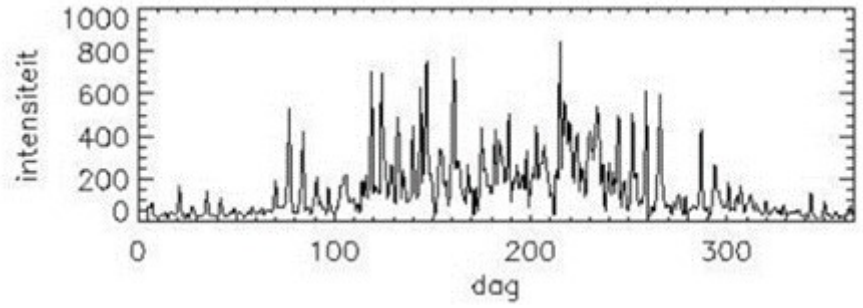


Figure 2: Intensity of cyclists in the year 1993 (Thomas, Tutamwebwa and Jaarsma, Rinus and Tutert, S.I.A., 2007)

In the paper (Petrovic, Ivanovic, Doric and Jovic, 2020) the weather influence is once more acknowledged; it indicates there is a "non-negligible influence of weather conditions on the transport demand and mode choice".

4 Methodology

In this chapter the methodology of the project is explained. For each research question it is explained how the results stated in chapter 5 were obtained.

Research question 1: What requirements, based of the mobility/bike vision, must a method meet?

The method to obtain results for this research question was split in two parts, desk research and expert meetings.

Desk-research
The desk research involved the reading of municipal policy that had a connection to mobility. Because the use of modal split within the municipality is limited to a role as indicator for its mobility goals, the municipal visions made an excellent starting point for setting up requirements. The visions that were included in this part of the research were:

- *Mobiliteitsvisie* - The mobility vision provided information on what the municipality strives to achieve with regards to mobility. Extracting the information related to modal split, gave insight in what is required from a method to calculate modal split.
- *Fietsvisie* - The bike vision is an extension of the mobility vision, and has its focus on how to improve cycling quality. With more specific goals for cycling it provided additional requirements on what is necessary from modal split.

Expert meetings
After conducting the desk-research, it became clear more information was needed on the usage of modal split within the municipality. For example the time-span after which results should be generated did not become clear by reading the visions. The additional information was gathered through the means of meetings with experts.

Thus meetings are meant to give better insight in the usage of modal split within the municipality, as desk-research did not provide this information. And as little information was known about the use of modal split in the municipality before hand, the decision was made to conduct meetings as unstructured interviews. The unstructured manner in which the meetings were held allowed for large amounts of information to be gathered, as information was not limited by the relevance of it to predetermined questions.

Research question 2: Based on the requirements which methods are viable options to implement in the municipality of Enschede?

In order to gain an answer to the second research question, an assessment of the different methods is conducted on the requirements that followed from research question 1. However when setting up these requirements, it became clear that not all the requirements were a must have requirement but rather wishes of the municipality. In the list of requirements that can be

found in chapter 5.1.3, a division was made between these wishes (named would like to have requirements) and the must have requirements.

During the assessment this separation was continued, by splitting the assessment into two parts. First the must have requirements, the requirements that are essential to measure the progress of policy goals, the main use of modal split in the municipality. Then second the assessment of the would like to have requirements, this is where methods can gain an advantage when it was able to meet the wishes of the municipality.

The necessary information to conduct the assessment was gained through literature, literature in the form of papers, news articles etc. When reading this literature it became apparent, that assessing the methods just on the requirements would leave out criteria that defines the performance of a method. Therefore research is conducted on which of these criteria are important to influence the decision making process to determine most viable method for the municipality to use. Additionally an assessment of the methods on these criteria is performed.

Ovia
Although Ovia is a survey-based method, it will be assessed separately throughout the assessment. The reason is the freedom that accompanies a survey based program run by the municipality itself, rather than be limited by what is measured by another party (CBS in the case of Odin).

Furthermore during the assessment, the decision was made to assess Ovia as if it was run by the municipality of Enschede. Meaning that even though an requirement of criteria is not met by the program Ovia, it can be achieved if the municipality sets up a similar program. These potential changes are reflected in the results of the assessment.

Research question 3: What is required in order to make the most suitable option (best method to calculate modal split) function within the municipality of Enschede?

To properly research a possible implementation of the method smartphone-tracking through the use of Fietstad Enschede, research into data of the app was conducted. The data in question was a data-set consisting of trips registered by the app between the 1st of June 2020 and the 30th of may 2021, 364 days which makes 52 full weeks.

First step was calculating the modal split from the data-set. And then comparing the calculated modal split, to modal split from the area of the municipality of Enschede determined by the Odin research. The comparison was conducted to establish if both methods generate similar results. And if that is not the case, use the comparison to find the causes and possible problems that create the differences. The use of Odin data was possible as research into the modal split of the municipality based on results from Odin was already conducted by Keypoint Consultancy. Keypoint was then found willing to give access to that data for use in this project. The used data-set contains data of the year 2018 which was the last year from which Keypoint had data.

5 Results

5.1 Requirements

Starting off with the results of the first research question; What requirements, based of the mobility/bike vision, must a method meet?

5.1.1 Desk-research

First the results of the desk-research, that involved the research into municipal policy with a relation to mobility.

The majority of the municipal policy with a relation to mobility is stated in their mobility vision. The focus of the research into the mobility vision went to the second chapter of the document. This is the chapter where the vision of the municipality is put into policy goals. The policy goals that require modal split as indicator to measure progress are summarized below:

Mobiliteitsvisie (Gemeente Enschede, 2019)

- Decrease internal car traffic with at least 10% by 2030.
- Further growth of bike-traffic, share-systems, public transport and walking.

Next to the mobility vision its extension fiets vision is included in the research. The focus for the fiets vision went to the third chapter, similar to second chapter of the mobility vision this is where the policy goals are stated. Results of the research into the fiets visie are summarized below:

Fietsvisie (Gemeente Enschede, 2021)

- Reduce the number of car-trips with at least 10%.
- Increase the share of cycling on short distances (up to 7.5 km) by 2030 to at least 50%.
- Specific for the middle-long distances (7.5 km to 15 km), an increase for the share of bike-trips from 19% to 30% in 2030.
- Optional: An analysis for the share of bike trips for very short trips (up to 2 km). In the bike vision an analysis was conducted on share of bikes on very short trips, monitoring the same situation over more years would be ideal.

5.1.2 Expert meetings

Besides the requirements that followed from the desk research, meetings with experts were held to gather additional information on modal split usage within the municipality.

A total of four meetings were conducted, the experts included two policy advisors mobility and a senior policy advisor mobility from the municipality. Plus an advisor mobility and space from Goudappel, Goudappel being a consultancy firm which were involved in creating both bike and mobility visions. Meetings were held with the employees of the municipality as they use the modal split, and can describe use of the modal split within the municipality. Moreover with their knowledge on modal split they can express what is required from modal split. The meeting with the employee of Goudappel was held as the employee was involved within the creation of the fiets vision, which included calculating modal split for each neighbourhood of the municipality.

From these meetings a significant amount of information was gained, however not all this information is listed in this chapter as not everything is relevant. Whether something is relevant depends on whether it can be translated into a requirement for a method.

Shared car
One thing mentioned by experts is the inclusion of a shared mobility mode, an example of shared mobility is the shared bikes (OV-fiets) which can be found at most train stations nowadays. The municipality is exploring the possibility of adding shared cars to the region, and would like more insight in shared car mode through the means of modal split ones plans are implemented.

E-bike
Another point of interest mentioned by experts is the separation of cycling into the branches E-bike and standard bike as a requirement for a method. With the rise of the E-bike in recent years it is seen as an alternative for the car on trips of middle-long distances. This development has not gone unnoticed at the municipality and plans are made that include E-bikes, thus insight is required into E-bike's mobility share.

Decrease amount of trips
Besides the addition of mobility modes, experts also mentioned that a big goal of the municipality is to not just decrease car traffic but the amount of trips in general. They try to achieve this by for example encouraging to work from home. A requirement is then; a method allows for the monitoring of total amount of trips.

Time-span
Lastly mentioned by experts is the agreement to structurally monitor the progress of policy goals. This agreement was included in their year plan, and in its basics states that monitoring of goals should happen on a yearly basis. Thus modal split as indicator for policy goals must be determined on a yearly basis.

5.1.3 Synthesis

From the desk-research and the meetings with the experts of the municipality a list of requirements that a method must meet is setup, this list of requirements can be found below:

Must have:

- Mobility modes that must be included within modal split results:
  - Walking
  - Bike
  - Car
  - Public transport
- The generation of results by a method must occur on a yearly basis.
- Distances that must be included within modal split results:
  - Short distance trips, up to 7.5 km.
  - Middle-long distances trips, from 7.5 km to 15 km.

Would like to have:

- Mobility modes that the municipality would like to include in modal split:
  - E-bike
  - Shared-car
- Distances that the municipality would like to include within modal split results:
  - Very-short distance trips, below 2 km.
- A method allows for the monitoring of total amount of trips.

A requirement is listed as must have when it is essential to measuring progress of policy goals, the main use of modal split within the municipality. The would like to have are wishes from employees of the municipality, and problems do not occur if the method to calculate modal split cannot meet them.

5.2 Assessment methods

With the requirements for methods setup, list of requirements can be found in chapter 5.1.3, an assessment on each method can be performed. This assessment is split in three parts, first the assessment of methods on must have requirements, second an assessment on the would like to have requirements. And last an assessment on additional criteria that have an influence on the decision making.

More information on the manner in which the assessment is conducted can be found in chapter 4. For more information on the results stated in this chapter check appendix A, where the assessment results for each individual method is stated.

5.2.1 Must have requirements

As the assessment is split up in three parts, the results are presented in three parts as well. First the results of assessment of methods based on the must have requirements, these results can be found in table 9.

Table 1: Results assessment of methods on must have requirements, an x represents a requirement is met

	Survey based	*OVIA*	*Induction loops*	*Smartphone tracking*	*WiFi/Bluetooth trackers*
Mobility mode					
Walking	x	x		x	
Bike	x	x	x	x	x
Car	x	x		x	x
Public transport	x	x		x	x
Requirement					
Time-span: yearly basis	x	x	x	x	x
Classification trips on distances	x	x		x	

In table 9 it can be seen that three methods survey-based, Ovia & smartphone-tracking meet all the requirements. On the other hand FietsViewer and WiFi/Bluetooth trackers not only lack the ability to classify trips based on the travelled distance, but do not gain information on all the required mobility modes either.

From the results in table 9 it becomes obvious that time-span will not be a problem regardless of the chosen method. A note that should be made is that even though the time-span of Ovia

is two years, this can be changed by the municipality of Enschede if they were to implement a similar program and thus it meets the requirement.

5.2.2 Would like to have requirements

Next are the results of the assessment of methods on the would like to have requirements, results can be found in table 2. By meeting would like to have requirements a method can gain an advantage, on the other and if a requirement is not met a method would not be discarded as an option.

Table 2: Results assessment of methods on would like to have requirements, an x represents a requirement is met

	Survey based	*OVIA*	*Induction loops*	*Smartphone tracking*	*WiFi/Bluetooth trackers*
Mobility mode					
E-bike		x			
Shared car		x			
Requirement					
Monitoring total amount of trips	x	x		x	

What is visualized in table 2 is that methods as FietsViewer and WiFi/Bluetooth trackers are unable to monitor total amount of trips, meaning that the other methods gain a slight edge over them. Moreover Ovia's adaptability gives it an advantage over other methods like survey-based and smartphone tracking, as it would be able to include mobility modes E-bike and shared car.

5.2.3 Additional criteria

And lastly the assessment of the methods on criteria that have an influence on decision-making.

Criteria for assessment

From the literature used in this study, it became obvious that with the current set of requirements important aspects of methods are not included in the assessment. The first aspect is the sample-size achieved by using a method. The Canadian study (Nurul Habib, Khandker and El-Assi, Wafic, 2016) in particular, shows the importance of a big sample to the confidence with which results can be stated. Additionally the municipality is interested in alternative methods because of the small sample achieved by the currently used method Odin.

Besides the sample-size, costs is stated as in important aspect of modal split in the literature. In (Harmen van Dorsser, Hans Wolfrat, William van Genugten, 2016) costs is given as a disadvantage of traditional survey-based methods compared to WiFi/Bluetooth trackers. Moreover the municipality of Enschede has made it clear limited funds are available, adding to the importance of costs in establishing which method is most suitable.

Based on literature the following criteria are added to the assessment:

- Costs - cost to run a program based on that method.
- Sample-size - Projected sample size a program based on that method could reach.

Assessment on additional criteria
The results of the assessment are visualized in figure 3, where the costs are set out against the sample-size. The figure is an estimate however, due to lack of information on exact numbers for costs and sample-size. For instance for Odin (national survey-based program) the sample-size is known on national level, but not specific for the municipality of Enschede. Because the results of the assessment are estimates they are put in classes.

For the assessment on additional criteria methods induction loops and WiFi/Bluetooth trackers are excluded. Both these methods are proven to be unable to meet must have requirements. Therefore they are not viable options to the municipality, and is unnecessary to assess on additional criteria.

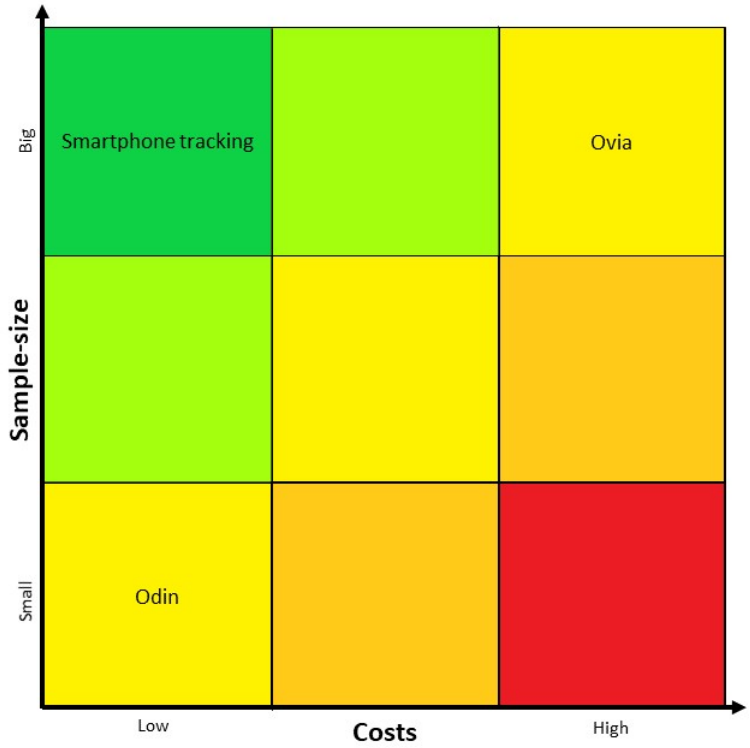


Figure 3: Costs against sample-size

Odin is assessed as low costs, as most costs are covered by Rijkswaterstaat (the party instigating the research program). Besides low costs Odin has a small sample-size when boxing in the region to just a municipality.

Ovia is assessed as high costs, the high costs stem from reaching out to inhabitants and pushing them to participate in the program. The assessment of high sample-size is based on the freedom gained by using Ovia, the necessary sample-size can be achieved by inviting more residents to participate.

Smartphone tracking is estimated as big sample-size based on the number of users of Fietstad Enschede. The app has a similar setup as the apps used in the sources (Tom Thomas, Karst Geurs, Marcel Bijlsma and Salima Douhou, 2014) & (Norbert Brändle, 2021). Therefore the assumption is made that the number of users, represents an estimate for smartphone tracking sample size. With 1146 users (Empower, nd) in the municipality it is estimated to have a bigger sample size than Odin. The estimation of the costs of smartphone tracking is based on the assumption that an app already exists, thus just small costs will be made in maintaining the app and processing the data. However if a suitable app is not available, and needs to be developed, the initial cost will rise massively and is estimated as high costs.

5.2.4 Synthesis

From the assessment the conclusion can be drawn that, FietsViewer & WiFi/Bluetooth trackers do not fit with what the municipality requires from a method that calculates modal split. In both cases they do not include all the necessary mobility modes (see table 9). And their inability to

classify trips based on the travelled distance, means the municipality would be unable to monitor the progress on their policy goals.

Three methods meet all the must have requirements; survey based, smartphone tracking and Ovia. From these methods Ovia scores best on the would like to have requirements, it gains an advantage over the other methods as it can include mobility modes E-bike and shared car. However the high costs made maintaining a program like Ovia, means it is only reserved for the biggest municipalities.

Thus two viable options for the municipality; sticking with survey-based thus modal split via Odin or use of smartphone-tracking. Comparing both methods in figure 3 shows that smartphone-tracking is estimated to have a bigger sample than Odin. With MRA added to survey based it is able to close this gap, but the increase in cost with MRA means smartphone tracking is the more suitable option. A note that should be made is that it is assumed an app is available to conduct smartphone tracking. If an app is not available; survey based with additional MRA and smartphone tracking are on a similar level regarding suitability.

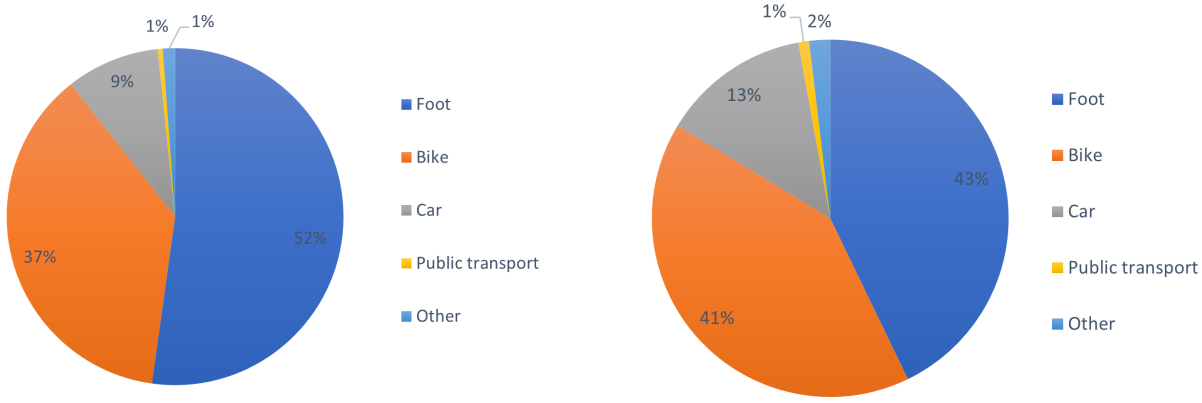
5.3 Using Smartphone tracking to determine modal split

The conclusion of research question 2 is that smartphone-tracking is the most suitable option for the municipality of Enschede to calculate modal split. This is under the assumption that an app is available to conduct the smartphone tracking with. For the municipality such an app is available; Fietstad Enschede. In this chapter using Fietstad Enschede app to determine modal split is further explored. Can the app be used as a source of information to calculate modal split? What problems come with using the the app, and how can these be solved?

5.3.1 Trip or distance based modal split?

Currently the municipality bases its modal split on the number of trips made per mobility mode. However the app has difficulty picking the exact moments where a trip starts and ends (Based on experiences from Johan Koolwaaij from Mobidot and using the app myself), meaning that on occasion the app registers a single trip as multiple trips or the other way around.

To counter this issue, modal split will be based on travelled distance instead. An example to show the difference in approach: when two trips on the bike are made both of 6 km, then with the trip based approach it would contribute as two trips made on the bike. But with the distance approach these trips would contribute as 12 km for the bike. Figure 4 visualizes the difference between trip based and distance based modal split.



(a) Trip based modal split

(b) Distance based modal split

Figure 4: Trip vs distance based modal split, determined from Fietstad Enschede data, for trips up to 7.5 km

The difference in modal split visualized in figure 4, cannot be entirely contributed to eliminating false contributions of split up trips. Part of the difference can be accounted to the change in impact of a contribution from a trip. With number of trips, a 2 km walking trip has equal impact as a 7 km bike trip. With travelled distance the impact of the bike trip becomes larger than the walking trip.

The change in calculating modal split means that moving forward modal split will be calculated using the following equation:

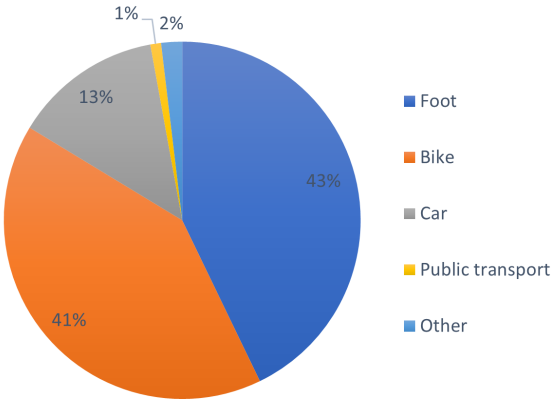
$$\text{Percentage mobility mode} = \frac{\text{Travelled distance with mobility mode}}{\text{Total travelled distance all mobility modes}} * 100 \qquad (1)$$

5.3.2 Modal split from Fietstad Enschede data

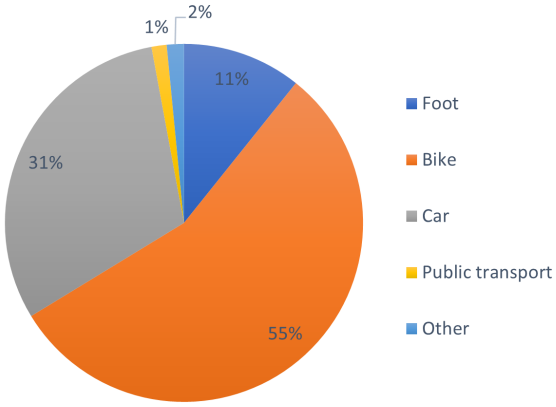
With the initial issue out of the way the modal split is calculated, as stated in the requirements the modal split is displayed in two distance classes: 0 to 7.5 km & 7.5 km to 15 km. The resulting modal split can be found in sub-figures 5a & 5b.

When comparing the modal split that is calculated from the Fietstad Enschede app data to modal split that was calculated using Odin (sub-figures 5c & 5d) there are differences. Which can in part be contributed to the difference in circumstances of the results of the two years. Fietstad Enschede results are from begin June 2020 to end of May 2021, and Odin results are from 2018. The main difference being the corona crisis that caused; working from home, not allowed to make visits etc. therefore less trips in the car were made. Moreover closing of sport centres meant alternatives had to be found like cycling and walking to stay healthy. All this contributed to a larger share of cycling and walking in the modal split.

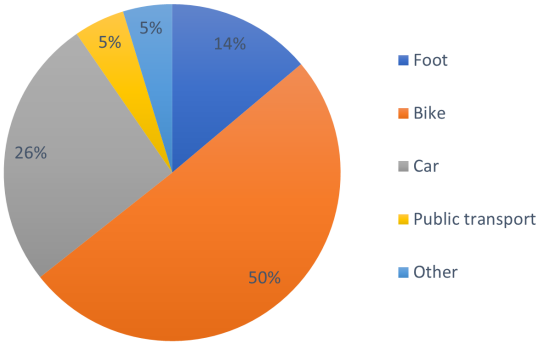
However the difference cannot be entirely contributed to the difference between years, and thus corona crisis. Due to the design of the Fietstad Enschede app it is more attractive to persons that already cycle more than average. As rewards are given for cycling more. Thus the design of the app creates a bias in the sample, a big disadvantage of using Fietstad Enschede app to implement smartphone tracking.



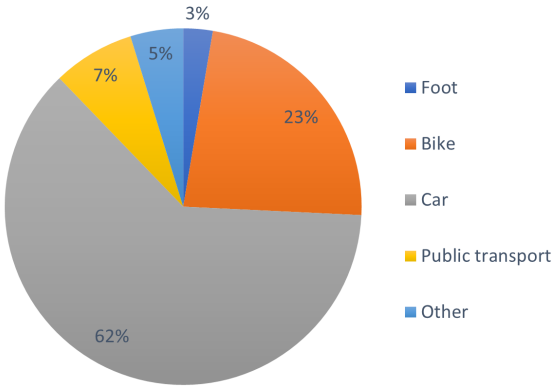
(a) Fietstad Enschede up to 7.5km



(b) Fietstad Enschede 7.5 to 15km



(c) Odin up to 7.5km



(d) Odin 7.5 to 15 km

Figure 5: Modal split Fietstad Enschede vs modal split Odin (Exact numbers in appendix B)

5.3.3 Countering the bias

The problem with the bias is that gathering data for modal split would be a secondary purpose of the app, the first being the promotion of the bike in the area of Enschede. Meaning that no changes will be made to the design of the app in favor of getting a more complete modal split from its data. This together with the situation that no other suitable apps are currently available, means adjustments to the method are required to counter the bias.

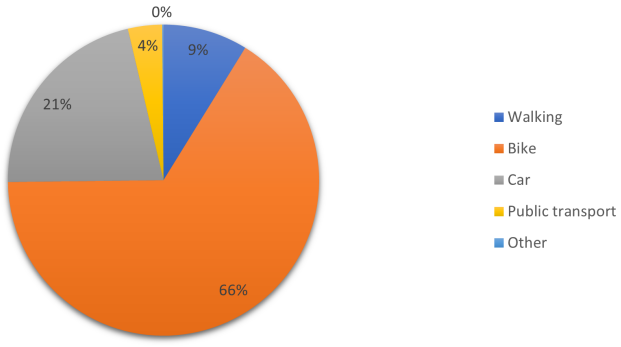
Cleaning data

The first proposed adjustment is cleaning the data of certain type of trips. Two types of trips are removed, the first being trips that fall outside the scope, chapter 3.2.2, trips that do not begin or end in the municipality of Enschede and thus of no interest. And second the leisure trips that from here on out will be called round trips (begin and end at the same point). The removal of these leisure trips is proposed to attempt to mitigate the influence of the bias on

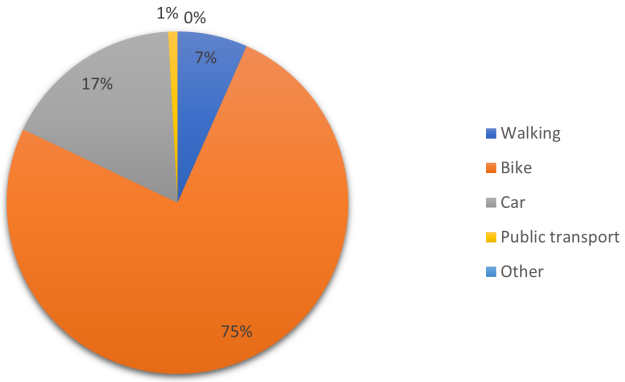
the results. Inhabitants that make a hobby out of cycling produce these leisure trips, therefore to limit their contribution to modal split these leisure trips are removed.

For removing the round trips the coordinates of the begin and end location were used. For both the longitude and latitude the differences between start and end was calculated, and if both the differences in longitude and latitude were 0m the trip was removed from the data-set. The limit of 0m could be taken because the app uses clipping points to determine start and end locations (Based of information from Mobidot). Meaning that when a trip begins and ends the app puts the start and end location on the nearest clipping point, and with a round trip this will be the same clipping point thus the same coordinates.

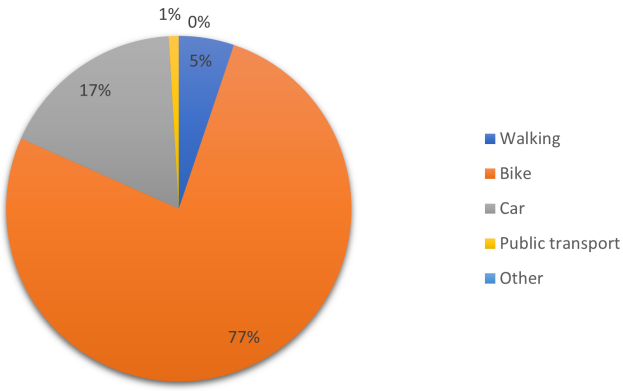
Trips outside of the scope were removed based on the information collected by the app on the start and end location. Specifically the city where the start and end location lie in, if neither the start or end location lie within Enschede the trip was removed.



(a) Modal split from raw data



(b) Modal split, without trips outside Enschede



(c) Modal split without round trips & trips outside Enschede

Figure 6: Results from cleaning app data of uninteresting trips (Exact numbers in appendix C), modal split from trips between 0 & 15 km of length

From the differences between sub-figures 6b & 6c the conclusion is drawn that including round trips or excluding them does not make a substantial difference. Therefore removal of round trips would not contribute to countering the bias.

Because of privacy it was not allowed to access and use data from all the users. But two

users were found willing to give access to their data with which the cleaning of data was conducted. The proposed method of cleaning the data conducted on two users can be expropriated to the entirety of the sample.

Recruit additional users

A second adjustment is creating a program in which inhabitants are payed to use the app, rather than recruiting on a volunteer basis. By adding a money reward it will become more attractive to use the app even when cycling is not your your hobby. However in order to maximize the potential of payment a random sample must be created, not add users to attempt to eliminate the bias in the current group of users. The reason being that to address the bias, people with opposite behaviour of the already existing group must be recruited. This will create a situation where a sample is forced to become what seems representative, but might actually be. Thus a random sample separate from the already existing group of users is required.

Although recruitment using payment has advantages, it also has a downside which are the costs. To keep the costs low, a certain period of the year can be selected to gather data rather than conducting it the entire year. With the use of a smaller period the the costs are driven down, and modal split can still be calculated albeit based on less data.

To determine a suitable length and the time of the year for a data gathering period graphs were made of modal split per day (figure 9 appendix D) per week (figure 10 appendix D) and per month (figure 7).

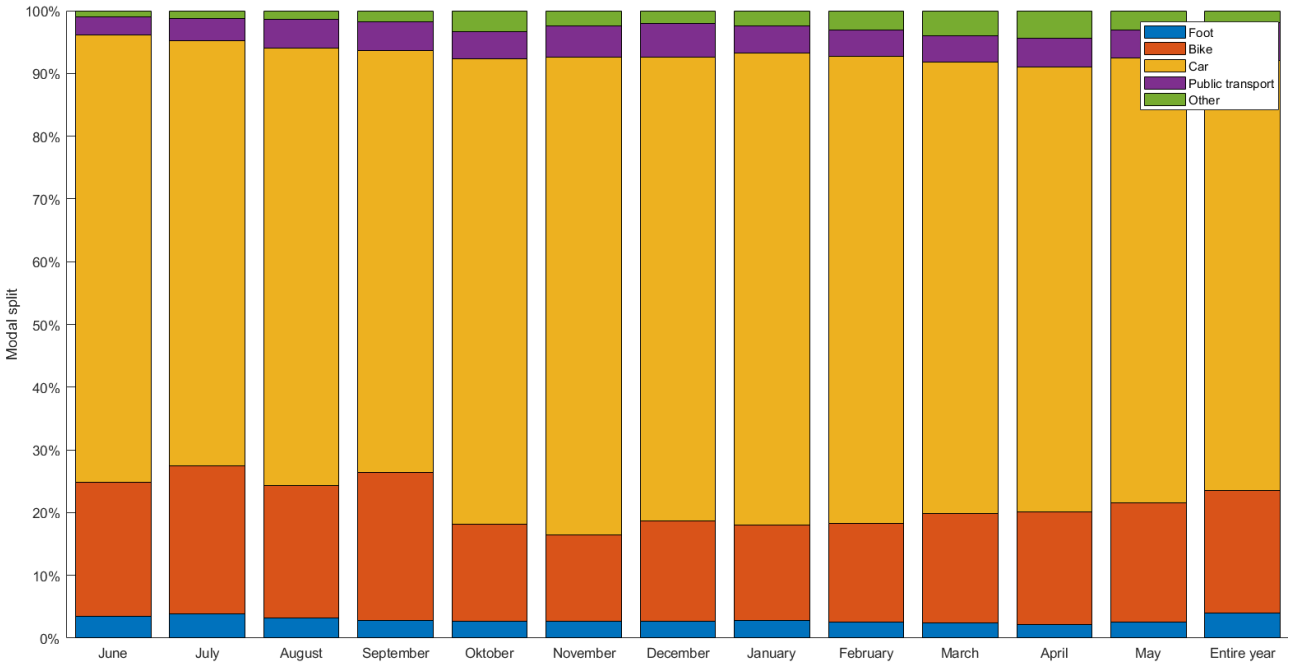


Figure 7: Modal split per month based of app data plus modal split for entire year

From figure 7 and the figures 9 & 10 in appendix D, the conclusion can be drawn that taking a period of a single day will not work. The influence of weather that can be seen in figure 9 in appendix D by the fluctuation in the graph, would give large differences for the same day

every year. Making it impossible to draw any conclusions form it with regards to the working of policies, the main use of modal split by the municipality.

Using a period of a week would yield a more consistent result, but weather continues to have an influence. This is presented most clearly by week 37 in figure 10 appendix D, and the effect that two days of snow has on modal split. The most consistent option would be to take a period of a month. As taking a period of a month would mean modal split of approximately four weeks is averaged out, thus further limiting the influence of weather. However where the influence of weather changes between short periods of times is limited by the use of a month, the influence of seasonal change becomes more clear. And in choosing a month this seasonal change should be taken into account.

Weather effect

Although the weather influence is mitigated with use of a month, it is not completely eradicated. The severity in which a month is still influenced by weather differs for each month of the year. The severity of weather influence is important in determining the best month to measure, as it will influence the consistency of results over the years. Meaning that for a month with bigger influence of weather, consistency is lower and trends are more difficult to determine.

Because data of only a single year exists, it was not possible to determine the consistency of modal split of a month over multiple years. Therefore the influence of weather in a month is calculated using standard deviation, where data points are; modal split of single days, and mean is; modal split of the month. The standard deviation is calculated for each mobility mode, resulting in the following equation:

$$\sigma_j = \sqrt{\frac{\sum_n^{i=1}(x_{i,j} - \bar{x}_j)}{n-1}} \tag{2}$$

Where:
σ_j = standard deviation of mobility mode j for a month
x_i = share of mobility mode j on day i
$\bar{x}_{i,j}$ = share of mobility mode j of a month
n = number of days in month

The standard deviation shows what is normal variation between modal splits of days, a variation which can mainly be attributed to change in weather conditions. Thus with lower calculated standard deviation, less weather influence, more consistency over years. Figure 8 shows the resulting standard deviation for each month on each mobility mode.

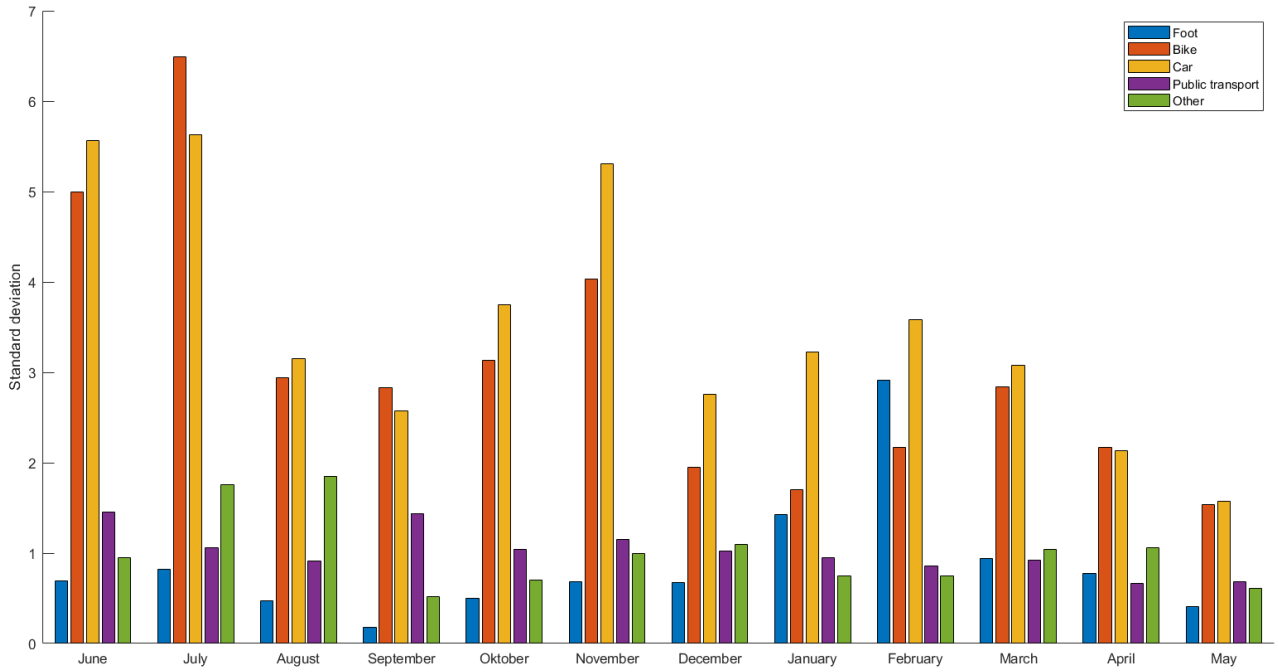


Figure 8: Weather effect per mobility mode for each month

From figures 7 & 8 the conclusion can be drawn that the month May is the best month to gather additional users to calculate modal split. The modal split of the month closely resembles the modal split of the entire year. And with the small standard deviation a high consistency over years is expected.

5.3.4 NVP

An alternative to the Fietstad Enschede app for implementation of smartphone tracking is NVP (Nationaal verplaatsingspanel). NVP is a research that uses smartphone tracking to gain insight in the traffic situation of the Netherlands, and establishing modal split is part of the research.

The problem NVP has is the sample-size, NVP has around 5000 daily participants and data of around 13000 (Dat.mobility, nd) in the entire Netherlands, less than ODin which already considered having a small sample. But this problem can be solved by setting up a program to recruit more participants to the program, a program comparable to what is proposed to eliminate the bias from the sample of Fietstad Enschede.

6 Conclusion

Based on the results of the assessment of methods on the requirements and additional criteria, smartphone tracking proves to be the best method to calculate modal split for the municipality of Enschede. The method meets all the necessary requirements, and has low costs and big sample-size.

However issues with implementation of smartphone tracking, show it is a less suitable option than estimated in the assessment. The bias that exists when using Fietstad Enschede app, requires additional recruitment of users with the help of payment to counter it. Thus higher costs than initially estimated in the assessment. Moreover the alternative NVP requires additional participants, to create a sample big enough for meaningful conclusion to be drawn from it. Again more costs than estimated for smartphone tracking in the assessment. With these additional costs for smartphone-tracking, Odin becomes an option again. As the smaller sample can be solved by a program of extra recruitment like MRA & MRDH.

But smartphone tracking has the advantage of gathering more data of participants, even in a shorter time period. And from the two options to implement smartphone tracking in the municipality of Enschede NVP has the most potential. It has the advantage that the app design does not favor a type of traffic participant, like petrol heads or hobby cyclists for example.

To conclude the advice to the municipality of Enschede is to exploit the potential of the NVP program. And with additional recruitment a good sample can be created.

7 Discussion

In this chapter limitations of this study are presented.

First of all something to keep in mind with the results is regarding the assessment of additional criteria. As mentioned before the results as they are stated in the report are not based on actual numbers. For most methods precise information was lacking, or the translation of numbers of a method to that of the region of Enschede was not possible. Meaning that the results are based on the little information that was available, concluded from context and the usage of common sense.

Another limitation of this study concerns the comparison of modal split calculated from the Fietstad Enschede app data and modal split calculated from data collected by Odin. The comparison of the modal split is between data from completely different years. The data from the Enschede Fietstad app is from the start of June 2020 to the end of May 2021, and the data collected by Odin goes back to 2019. The main difference between the two year is the Covid-19 pandemic that broke out in the first months of 2020. The reason of this difference in years is that CBS did not continue with Odin throughout the Covid-19 pandemic, and that Mobidot does not store data of the Fietstad Enschede app longer than a year.

Furthermore the lack of data continues to limit the research when it came to finding the best period of the year to implement payed usage of the app. As the data-set only consisted of data from a single year it became difficult to determine consistency of for example a month over multiple years. A recommendation would be to check consistency of the month May, suggested by the results of this study, over at the very least two different years.

To counter the problem the app has with correctly registering the start and end of trips, it was decided to calculate modal split based on travelled distance rather than number of trips. However based on own experiences using the app this is not the only issue the app has, it also has difficulty determining the correct mobility mode which will have its affect on modal split.

Lastly the conclusion that including or excluding round trips does not have any impact, is based on data of just two users. With privacy the reason that a complete data-set was unavailable, two user were found willing to give access to their data. This does however mean that the conclusion cannot be made with much confidence. As the two users might not be persons making a lot of round trips, therefore limiting the impact of excluding the round trip.

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Appendices

A Assessment individual methods

Survey-based

Description:
Nowadays in the survey based methods like Ovin & Odin, randomly selected inhabitants of Netherlands receive a letter asking them to fill in an online questionnaire about their recent trips. Questions about the nature of the trip, length of trip and used mobility mode are asked. The information that the questions provide are then used to determine modal split for the Netherlands. (CBS, 2019)

Included mobility modes:

- Walking
- Bike
- Car
- Public transport

Classification of modal split based on distance:
In the online questionnaire information is gathered about the trips in general, length of the trips is a part of that information (CBS, 2019). Thus it is possible to classify the results within certain distance categories.

Time-span:
The results of Odin, the currently implemented survey-based method in the Netherlands, projects results on a yearly basis (CBS, 2019).

Monitoring total amount of trips:
The results of the Odin research includes average amount of trips per person per day (CBS, 2020). This information can be translated to the average amount of trips per person per year, and then using number of inhabitants to gain total amount of trips per year. Thus it is possible to monitor total trips using a survey-based method.

MRA & MRDH:
Because Ovin is a national research program it has its focus on the entire Netherlands, meaning that on a more regional level like a municipality the sample size becomes quite small. To counter this problem municipalities together with CBS have setup a programs called MRA & MRDH.

MRA or Metropoolregio Amsterdam is the name for a region around the city Amsterdam. In MRA the aim is to increase the number of respondents for Ovin/Odin in the MRA region (Vervoerregio Amsterdam, 2018). Thus gaining better insight into the modal split in the region.

MRDH or Metropool Rotterdam Den Haag is similar to MRA in its objective to increase the number of respondents in the region (CBS, 2020).

Costs:

Table 3: Costs for each survey-based program per year

Program	Odin 2019	MRA
Costs (€)	0	70,000

The costs of using the results from just the Odin research is €0.-, as the research is in general financed by Rijkswaterstaat (Vervoerregio Amsterdam, 2017). For the program named MRA additionally conducted by CBS, the MRA pays around €70,000.- a year for a total of 280,000.- between 2018-2021. (Vervoerregio Amsterdam, 2017)

Sample-size:

Table 4: Number of respondents for each survey-based program (CBS, 2020)

Program	Odin 2019	MRA	MRDH
# respondents	45320	2166	5894

The number of respondents in table 4 give a distorted view, first the Odin number is for the entire Netherlands. Furthermore for both MRA and MRDH the numbers are for the entire region, meaning the numbers represent respondents in multiple municipalities.

Result:

Table 5: Result assessment for survey-based method

Must have:		*Would like to have:*	
Mobility mode		**Mobility mode**	
Walking	x	E-bike	
Bike	x	Shared car	
Car	x		
Public transport	x	**Requirement**	
		Monitoring total amount of trips	x
Requirement			
Time-span: yearly basis	x		
Classification trips on distances	x		

Smartphone tracking

Description:
Smartphone tracking has presented itself as an viable option to get more insight in mobility. With the usage of a smartphone's advanced functions trips can be registered automatically with the help of an app. Information can be gathered on trip length, duration, average speed etc.

The idea of smartphone tracking is not new, and has been implemented in multiple researches already. There are three researches that will be studied in this project. The first is a research (Tom Thomas, Karst Geurs, Marcel Bijlsma and Salima Douhou, 2014) that uses an app called MoveSmarter, the second research (Norbert Brändle, 2021) which uses a similar approach as with the MoveSmarter. And the last research (Nederlands Verplaatsingspanel, nd) which is called NVP or nationaal verplaatsingpanel, a research that works on a national level.

Included mobility modes:

- Walking
- Bike
- Car
- Public transport

Classification of modal split based on distance:
Smartphone tracking in all three researches uses the function GPS to track the movement of a user, thus providing insight in the distance that a user covers on a trip. Allowing for the classification of trips based on its distance.

Time-span:
The tracking of trips occurs continuously, in the research NVP (Nederlands Verplaatsingspanel, nd) they go as far as to say it can provide valuable insights on a weekly basis. Therefore results from smartphone tracking is available every year.

Monitoring total amount of trips:
Like the survey-based methods the average amount of trips per person can be determined, thus monitoring total amount of trips can be conducted with smartphone tracking.

Enschede Fietst:
The municipality of Enschede uses an app called Enschede Fietst to promote the use of the bike (Enschede fietstad, nd). In recent years however ideas have grown to use the app-data for a second purpose, namely determination of modal split in the region of Enschede.

As the app registers the trips a user of the app makes, similar to the apps described in the papers (Tom Thomas, Karst Geurs, Marcel Bijlsma and Salima Douhou, 2014) & (Norbert Brändle, 2021), it provides data from which modal split could be calculated.

Sample-size:
NVP or nationaal verplaatsingspanel has currently collected data from 13,000 persons, 5000 of them participate in the program on a daily basis (Dat.mobility, nd). Thus effectively a sample size of 5000 for the entire Netherlands. The Enschede fietst app had 1146 users (Empower, nd) in 2017.

Result:

Table 6: Result assessment for smartphone tracking method

Must have:		*Would like to have:*	
Mobility mode		**Mobility mode**	
Walking	x	E-bike	
Bike	x	Shared car	
Car	x		
Public transport	x	**Requirement**	
		Monitoring total amount of trips	x
Requirement			
Time-span: yearly basis	x		
Classification trips on distances	x		

Ovia

Description:
OViA or onderzoek verplaatsingen in Amsterdam, is a research setup by the municipality of Amsterdam about 25 years ago (Gemeente Amsterdam, 2010). The research is survey-based and has similarities with Ovin/Odin. However there are differences between OViA and Ovin, where ovin produces results on a yearly basis ovia gains results every two years. Furthermore where data is gathered throughout the year in Ovin, with Ovia only in spring and autumn data is collected (Gemeente Amsterdam, 2019).

Included mobility modes:

- Walking
- Bike
- E-bike
- Car
- Public transport
- Shared car

Classification of modal split based on distance:
Similar to Ovin, OViA uses questionnaires that ask about information on trips. And from the results stated on page 46 in the Amsterdamse Thermometer van bereikbaarheid 2019 (Gemeente Amsterdam, 2019) it can be concluded that information on trip distance is asked.

Time-span:
In the case of OViA the results are produced every two years (Gemeente Amsterdam, 2019), however when setting up a research similar to OViA there is the possibility to reduce this time to a single year. Because the control over the research sits with the party instigating the research, it can be decided to produce results on a yearly basis. In that case, what should be kept in mind is that if research is conducted every year the costs will increase.

Monitoring total amount of trips:
In Amsterdamse Thermometer van bereikbaarheid 2019 (Gemeente Amsterdam, 2019) page 47 it is stated that the average inhabitant of Amsterdam makes 2.4 trips a day. Thus monitoring of total amount of trips can be achieved using a method like Ovia.

Result:

Table 7: Result assessment for Ovia

Must have:		*Would like to have:*	
Mobility mode		**Mobility mode**	
Walking	x	E-bike	x
Bike	x	Shared car	x
Car	x		
Public transport	x	**Requirement**	
		Monitoring total amount of trips	x
Requirement			
Time-span: yearly basis	x		
Classification trips on distances	x		

FietsViewer

Description:
The municipality of Den Haag uses an open source application called FietsViewer, which uses data from induction loops planted in bike lanes near cross-sections. The data shows the amount of cyclists passing a cross-section giving insight in the usage of the bike mobility mode, but also determines waiting times for cross-sections that have traffic lights (Marjolein van Trigt, 2019).

Included mobility modes:

- Bike

Classification of modal split based on distance:
Classifying trips based on distance cannot be achieved using a method based on an application like FietsViewer. The application only registers that a cyclist passes a certain cross-section, thus insight on a cyclists path, origin or destination is lacking. Missing this data means that length of a trip cannot be determined. (Marjolein van Trigt, 2019)

Time-span:
The application FietsViewer conducts measurements on a daily basis, therefore it allows for an aggregated result each year.

Monitoring total amount of trips:
With an application like FietsViewer monitoring total amount of trips is not possible. Where survey-based, smartphone tracking and Ovia follows and identifies individual users Fietsviewer does not. Therefore not giving insight into average number of trips inhabitants make.

Result:

Table 8: Result assessment for FietsViewer

Must have:		*Would like to have:*
Mobility mode		**Mobility mode**
Walking		E-bike
Bike	x	Shared car
Car		
Public transport		**Requirement**
		Monitoring total amount of trips
Requirement		
Time-span: yearly basis	x	
Classification trips on distances		

WiFi/Bluetooth trackers

Description:
With an increase in the use of modern technology: more cars have Bluetooth systems, more people use wireless headphones, increase in smartphone usage etc. The opportunity arises for the measuring of these appliances when they use WiFi or Bluetooth.

It works as followed, boxes are placed across the city which constantly count when an appliance that is connected to WiFi or Bluetooth passes by. Then using an appliance's unique codes paths can be determined when an appliance passes multiple trackers. (Harmen van Dorsser, Hans Wolfrat, William van Genugten, 2016) & (Anton Wijbenga, Jacob Bac, Steven Boerma, nd)

Included mobility modes:

- Bike (CIVITAS WIKI team, 2020)
- Car
- Public transport

Classification of modal split based on distance:
Classification of modal split based on distances cannot be done using WiFi/Bluetooth trackers. In for example the case of the Rotterdam harbor (Harmen van Dorsser, Hans Wolfrat, William van Genugten, 2016) the number of boxes is too low to accurately determine origin and destination.

Time-span:
WiFi/Bluetooth trackers measure traffic daily, and will allow for results on a yearly basis. (Harmen van Dorsser, Hans Wolfrat, William van Genugten, 2016)

Monitoring total amount of trips:
WiFi/Bluetooth trackers allows for the monitoring for total amount of trips based on the number of measurements each year.

Sample-size:
Similar to FietsViewer there is no clear sample and thus not a number for sample-size. However in the case of the Bluetooth trackers placed in the harbor of Rotterdam, with 85 Bluetooth trackers it managed to gain 2 million data entries (Harmen van Dorsser, Hans Wolfrat, William van Genugten, 2016).

Result:

Table 9: Result assessment for WiFi/Bluetooth trackers

Must have:		*Would like to have:*
Mobility mode		**Mobility mode**
Walking		E-bike
Bike	x	Shared car
Car	x	
Public transport	x	**Requirement**
		Monitoring total amount of trips
Requirement		
Time-span: yearly basis	x	
Classification trips on distances		

B Modal split from app data and Odin in numbers

Table 10: Modal split Enschede Fietst app, up to 7.5km

Mobility mode	Distance (km)	Share (%)
Foot	490050	42.82
Bike	467429	40.85
Car	154048	13.46
Public transport	11134	0.97
Other	21651	1.89

Table 11: Modal split Enschede Fietst app, 7.5 to 15 km

Mobility mode	Distance (km)	Share (%)
Foot	168567	10.74
Bike	871466	55.54
Car	483265	30.80
Public transport	21470	1.37
Other	24252	1.55

Table 12: Modal split Odin, up to 7.5km

Mobility mode	# trips	Share (%)
Foot	129	19.97
Bike	303	46.90
Car	214	33.13
Public transport	0	0.00
Other	0	0.00

Table 13: Modal split Odin, 7.5 to 15 km

Mobility mode	# trips	Share (%)
Foot	0	0.00%
Bike	21	20.59%
Car	81	79.41%
Public transport	0	0.00%
Other	0	0.00%

C Cleaning of data presented in numbers

Table 14: Numbers modal split from raw data.

Mobility mode	**Distance (km)**	**Modal split**
Walking	410	3.1%
Bike	4181	31.6%
Car	6309	47.6%
Public transport	2334	17.6%
Other	6	0.0%

Table 15: Numbers modal split, without trips outside Enschede

Mobility mode	**Distance (km)**	**Modal split**
Walking	264	2.8%
Bike	3850	41.3%
Car	4067	43.6%
Public transport	1143	12.3%
Other	0	0.0%

Table 16: Numbers, modal split without round trips & trips outside Enschede

Mobility mode	**Distance (km)**	**Modal split**
Walking	195	2.3%
Bike	3273	38.0%
Car	4004	46.5%
Public transport	1143	13.3%
Other	0	0.0%

D Graphs modal split per day and week

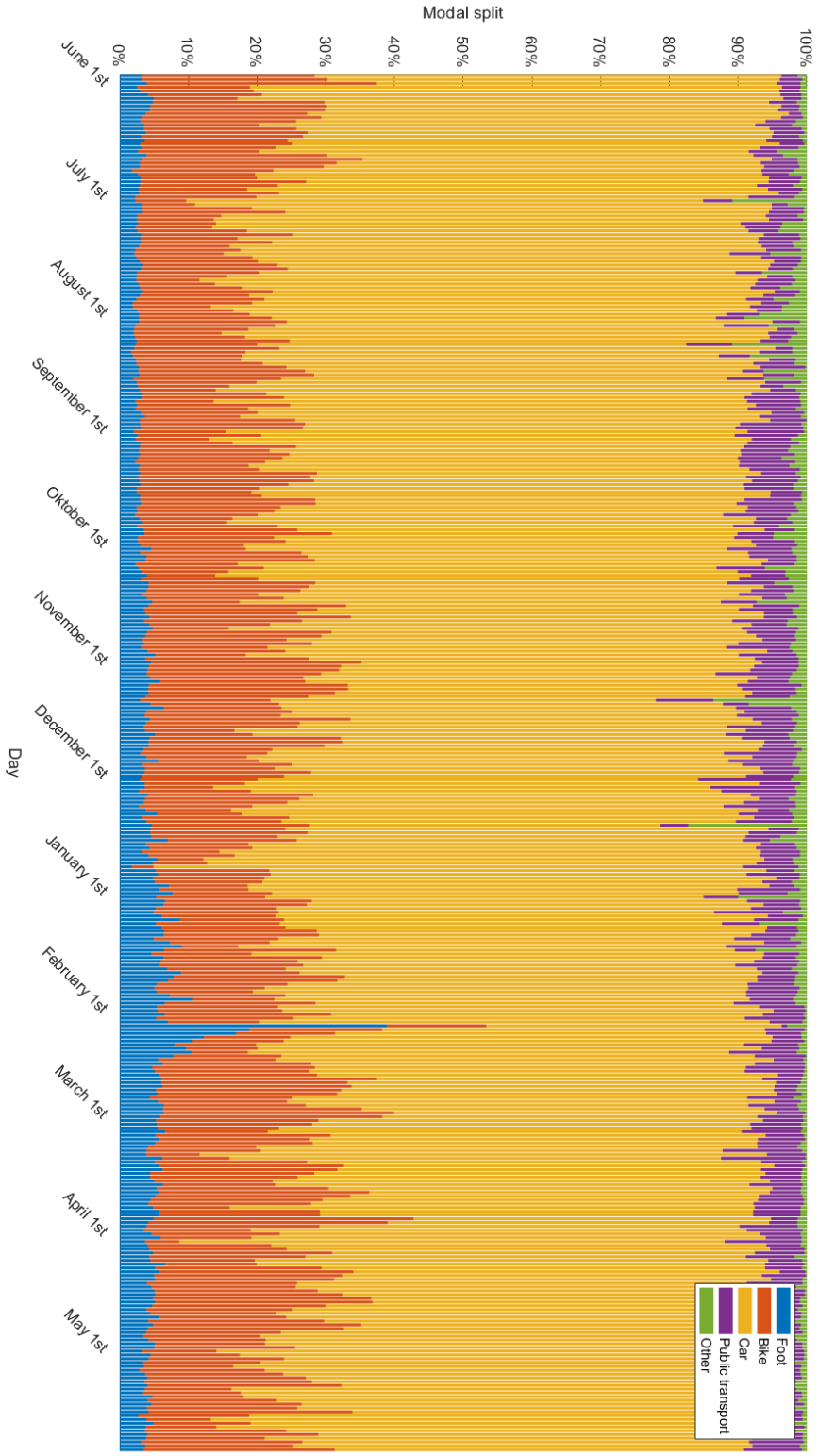

Figure 9: Modal split per day based of app data

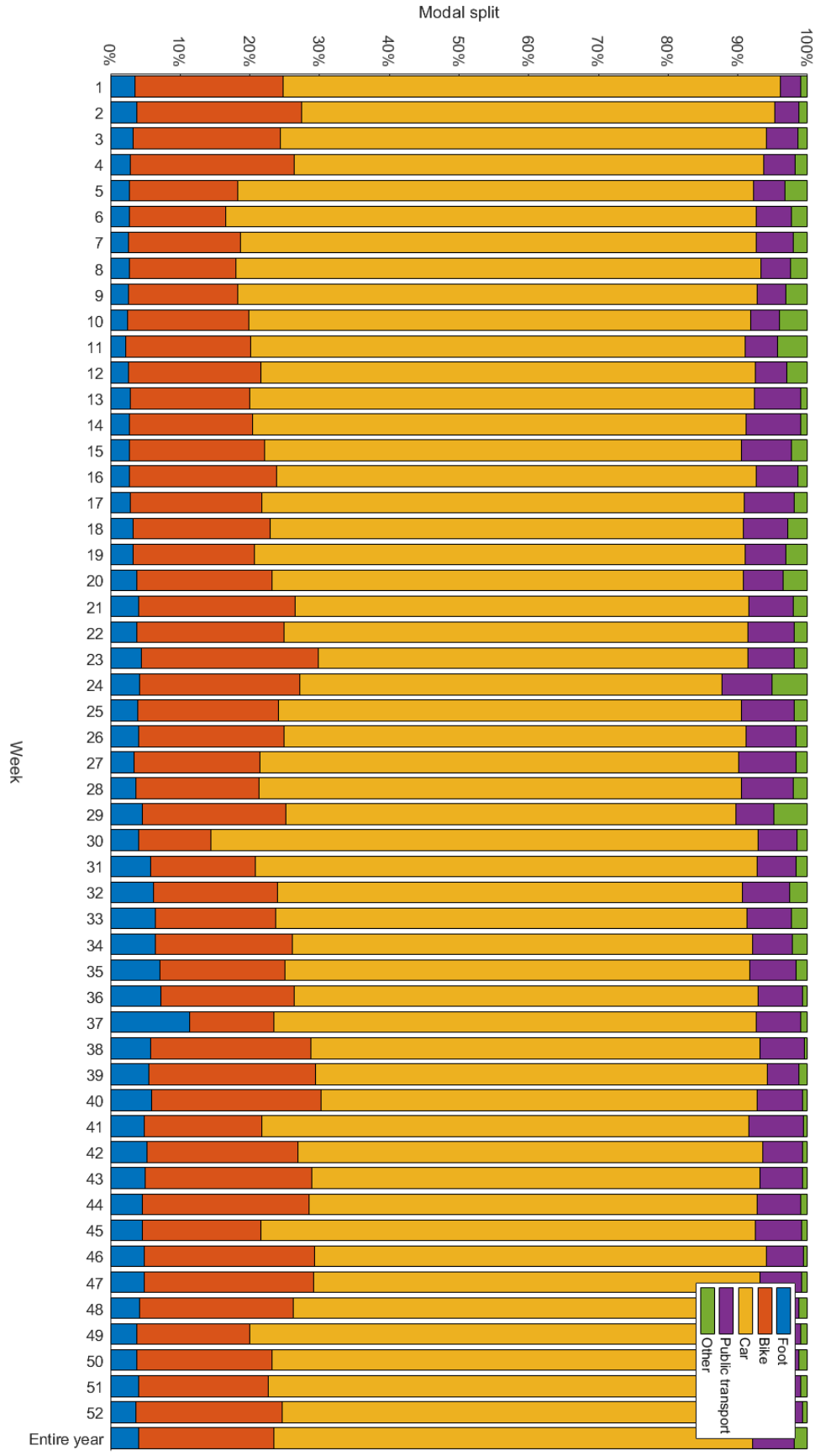

Figure 10: Modal split per week based of app data plus modal split for entire year