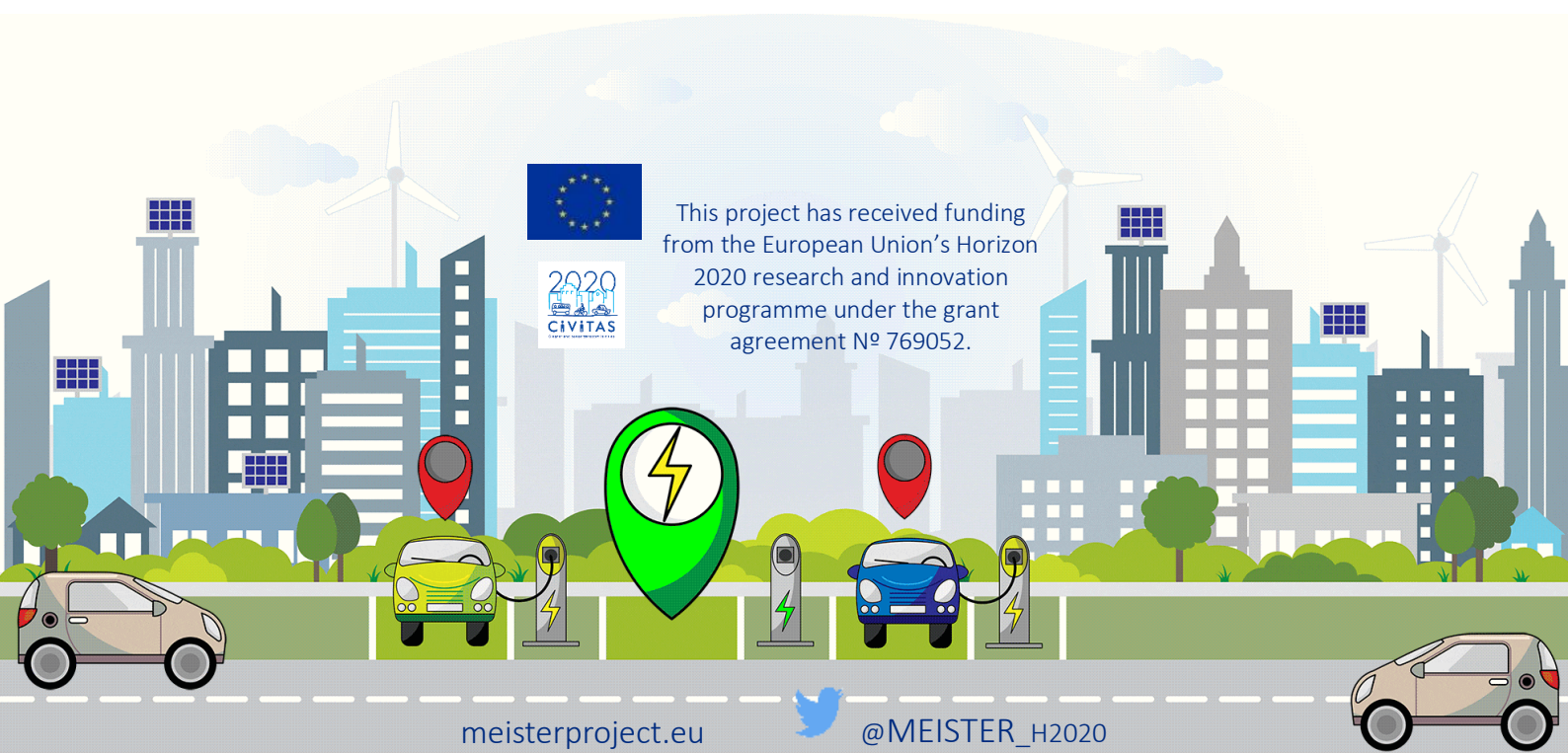


# Free-floating electric shared cars in Stockholm

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## SUMMARY

This report presents a study conducted by RISE and City of Stockholm as part of the Horizon 2020 project MEISTER. The aim was to increase knowledge of what possibilities and challenges that free-floating electric car-sharing entails, with a focus on how this service is used and how charging can be managed efficiently, to support City of Stockholm in their work with facilitating sustainable urban mobility.

In Stockholm, the company Aimo runs a free-floating car-sharing service with fully electric cars. Customers may leave the car in any valid parking spot within designated boundaries, where the next customer may pick it up. Customers are not required to charge the car; this is managed by Aimo. The study is mainly based on two questionnaires with Aimo customers, distributed in February-March and September 2020.

Results show that Aimo generally complements public transport: respondents use Aimo cars when public transport is inaccessible or impractical. There are often multiple persons in the shared car. In Stockholm, the average car occupancy is 1.2 persons per car, while the occupancy rate of Aimo cars is 1.6–1.7. Aimo is generally used for errands such as visiting family and friends, going shopping, transporting big or heavy items or taking children to sports activities. The main motivation for using Aimo is convenience; being able to get access to a car swiftly and spontaneously. The possibility to collect and return the car within a geographic area rather than a specific parking spot is attractive.

A conclusion is that free-floating shared electric cars can indeed contribute to sustainable urban mobility: they are largely used as a complement to public transport, for specific purposes, and there are often multiple persons in the shared car. However, with more free-floating electric shared cars, parking and charging could become a challenge. In the urban environment, space that may be used for parking is very valuable and its use is not a given. While car-sharing customers value a multitude of parking spaces, car-sharing providers value long-term parking, and charging providers value short-term parking. All of these actors value fast charging, which requires a bigger investment and higher power capacity than slower charging. This illuminates the importance of collaboration between urban planners, car-sharing providers and charging providers, to create a beneficial situation for car-sharing. This should be the focus of future studies.

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# 1 INTRODUCTION

Car-sharing services could play a big part in sustainable urban mobility. With inhabitants having access to a shared car when they need one, car ownership could be reduced. This would reduce the need for parking spaces and might also help reduce overall traffic and congestion.

Although car-sharing is not a new idea – car rental is a well-known concept – new business models have entered the market in the last few years. One of those new concepts is free-floating car-sharing, in which customers are free to leave the shared car in any valid parking spot within designated geographical boundaries. Other customers may then pick the car up from that parking spot and leave it at another. Thus, the shared cars are free-floating within a city or area.

In October 2018, a company called Aimo launched a free-floating car-sharing service comprising 300 fully electric cars in Stockholm. To increase knowledge of what possibilities and challenges that this kind of car-sharing entails, RISE and City of Stockholm have conducted the study presented in this report, as part of the Horizon 2020 project MEISTER<sup>1</sup>.

## 1.1 AIM

The aim of this study is to establish knowledge of how free-floating electric car-sharing is used, to support City of Stockholm in their ongoing work with creating and providing relevant physical and digital infrastructure for sustainable urban mobility. The study focusses on the following research questions:

- Why do people use Aimo car-sharing, and for what kind of trips?
- What mode of transport is replaced when someone chooses to use an Aimo car?
- How is charging of Aimo cars managed?
- With an increase in free-floating electric car-sharing, how could charging be managed efficiently?
- How can free-floating car-sharing contribute to sustainable urban mobility?

## 1.2 AIMO'S FREE-FLOATING SHARED CARS

Aimo is a mobility company owned by the Japanese investment company Sumitomo Corporation. Since October 2018, Aimo keeps 300 fully electric cars in free-floating car-sharing in central Stockholm. The number of cars has not fluctuated, it remained 300 over the period of this study. During a shorter period, Aimo also included electric scooters in their Stockholm service spectrum.

Aimo cars may be driven anywhere, but trips may only be started and finished within the 'homezone'. The homezone, where Aimo cars may be parked and picked up, encompasses parts of Stockholm, Solna, and Sundbyberg municipalities (as shown in Figure 1). Within the homezone there are 'hotspots', i.e., parking spots reserved for Aimo cars. Apart from hotspots, parking is valid in many streets within the homezone. An Aimo car may be left in any valid parking spot, where other Aimo users may pick it up. The service is app-based; cars are found, booked (up to 15 minutes in advance), and unlocked using the app.

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<sup>1</sup> <https://meisterproject.eu/>



**Figure 1. Aimo's homezone, as defined 2021-01-29. Map provided by Aimo.**

Aimo charges cars with low battery levels. Range estimations are shown in the app and only cars with more than 20 km range are available for hire. Aimo does not require users to charge the car. If charging is needed during hire, Aimo cars are charged for free at hotspots, but the driver pays for charging anywhere else.

## 2 METHOD AND MATERIAL

This study is based on data collected from Aimo users in 2020. Planning started in October 2019, with discussions between City of Stockholm, RISE, and Aimo, in which research questions, methodology, and a time plan were defined. RISE would be responsible for data collection and analysis, Aimo would contribute by distributing questionnaires to their customers, and City of Stockholm would contribute to the development of questionnaires and the analysis of results.

The initial plan was to collect data in two periods, in February and May 2020, to account for any differences in car use in different seasons. In February, the weather in Stockholm may well be considered an incentive for car use, while other alternatives might seem more attractive in May. However, with the pandemic, normal travel patterns were disrupted in March. As a consequence, the second data collection period was delayed until September 2020. Travel patterns were still disrupted, but the study needed to be completed. The timeline is presented in Table 1.

**Table 1. Timeline for data collection, year 2020.**

January	Questionnaire design
26 February – 3 March	Questionnaire distributed to Aimo users
9-12 March	Phone interviews with questionnaire respondents
22 April	Interview with Aimo representatives
12 May	Workshop with City of Stockholm
June	Questionnaire redesign
16-30 September	Questionnaire distributed to Aimo users

Data was collected in questionnaires that were sent electronically to those who used an Aimo car during the study periods. The initial questionnaire focussed on the respondent's most recent Aimo trip. The questions and response alternatives are presented in Appendix A. This questionnaire was

designed to be very short, as the anticipation was that recipients would not be inclined to respond to a longer questionnaire. Respondents could choose to answer anonymously but were asked to voluntarily provide their phone number, to be asked additional questions in a phone interview. The follow-up phone interviews covered more general travel habits. The structure of the phone interviews is presented in Appendix B.

The first questionnaire was distributed to 630 persons who used an Aimo car during the period 26 February to 3 March 2020 (a total of six days). 293 of the recipients completed it, giving a response rate of 46.5%. 113 respondents gave their phone number, and 35 of them were randomly selected and called by a researcher between 9 and 12 March 2020. When called, many were however not able to participate in a phone interview. Eventually, 14 questionnaire respondents were interviewed.

Given the high response rate and the willingness to answer additional questions, the questionnaire was redesigned for the second period. A few more questions were included, to cover not only the most recent Aimo trip but also travel habits in general. At the time of the second questionnaire period, the corona pandemic had led to changes in travel needs and travel patterns. Those who could were advised to work from home and avoid using public transport. Therefore, questions of travel habits, current and pre-pandemic, were also added. The questions and response alternatives are presented in Appendix C. In this questionnaire, all respondents remained anonymous.

The second questionnaire was distributed to 3684 persons who used an Aimo car during the period 16-30 September 2020 (a total of fifteen days). 671 of the recipients completed it, giving a response rate of 18.2%. 79% of respondents stated that they were Aimo users before the pandemic, which implies that they had been Aimo users at the time when the first questionnaire was distributed. It is unknown how many respondents received and completed both questionnaires. An overview of respondents is presented in Table 2.

**Table 2. Number of respondents in the different data collection periods.**

	<b>Questionnaire 1</b>	<b>Phone interviews</b>	<b>Questionnaire 2</b>
<b>Recipients</b>	630	35	3684
<b>Respondents</b>	293	14	671

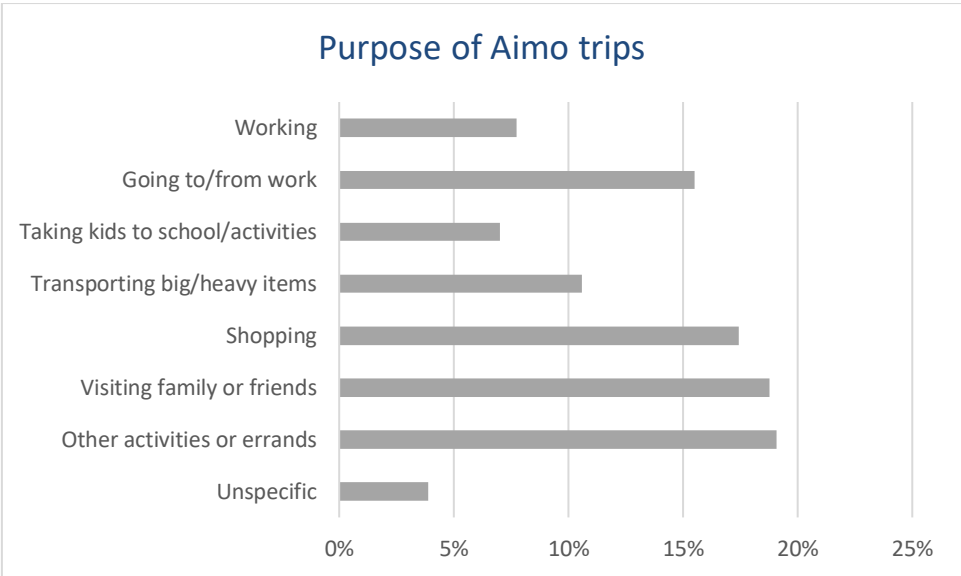
There are two big differences between the data collection periods: the number of questionnaire recipients and the response rate. With the pandemic and a general tendency to avoid crowding, Aimo has seen a rising customer base. Unfortunately, data of the increased customer base has not been shared and cannot be incorporated in this study. The differences in recipient number and response rate remain unexplained.

To complement the material collected from Aimo users, an interview with Aimo representatives was performed, with a focus on charging and distribution of cars. A workshop on charging and parking was also held, involving civil servants who work with City of Stockholm’s charging infrastructure planning. Both were executed virtually, the interview in April and the workshop in May 2020.

### 3 RESULTS

#### 3.1 PURPOSE OF AIMO TRIPS

In the questionnaires, respondents were asked if their most recent Aimo trip was made privately or at work, and if they had carried any kind of cargo. If the trip had been made privately, they were asked for the purpose. In the initial questionnaire, the respondents were asked to describe the purpose of the trip in their own words. From their responses, four main categories could be identified: going to or from shops, seeing friends or relatives, going to or from work, and transporting bulky or heavy items. In the second, redesigned questionnaire, these categories were incorporated as options for the respondents who could also choose ‘other’ and describe their purpose. Many of the answers to ‘other’ were detailed enough for further categorisation. Driving one’s children to school or sports practice turned out to be a frequent purpose. A multitude of other errands and activities could be discerned, e.g., doctor’s appointments and nature excursions. The results from the September questionnaire period are presented in Figure 2.



**Figure 2. Respondents’ stated purposes for their most recent Aimo trip. ‘Unspecific’ contains answers that could not be categorised. The graph is based on data from the September questionnaire with 671 respondents.**

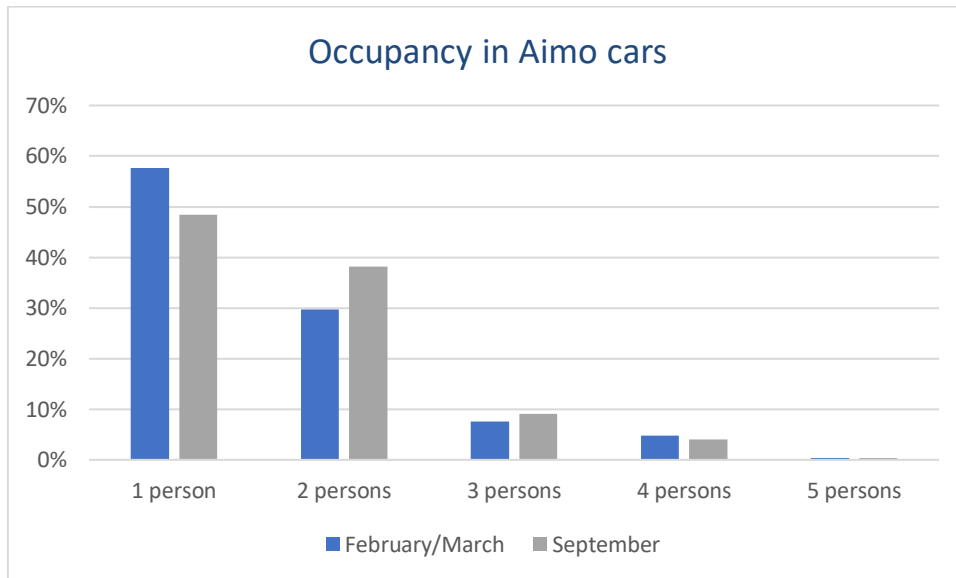
Most of the respondents used Aimo cars privately, and several brought cargo with them in the car, as Table 3 shows. Still, only 11% considered cargo transport to be the main purpose, as seen in Figure 2.

**Table 3. Share of respondents who used Aimo at work and/or to transport big or heavy items.**

	February/March	September
<b>Using Aimo car privately</b>	89%	92%
<b>Transporting big/heavy items</b>	39%	37%

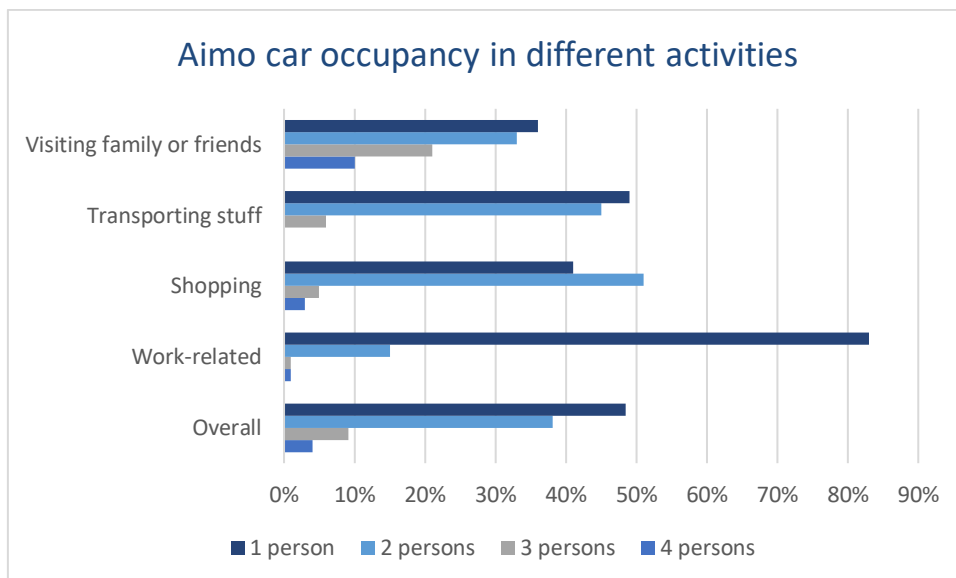
### 3.2 AIMO CAR OCCUPANCY

In both questionnaires, the respondents were asked if they made their most recent Aimo trip alone or in the company of others. The results indicate that there are often multiple persons in the Aimo car. According to City of Stockholm’s traffic surveys, the average occupancy is around 1.2 persons per car<sup>2</sup>. Data from this study puts occupancy rate at 1.6 in the first study period and 1.7 in the second. Figure 3 illustrates the occupancy given data from the two questionnaires.



**Figure 3. Number of persons travelling in the Aimo car in the two questionnaires. In a few cases, there were five persons in the car, but the percentage is very low.**

With the material gathered in the second questionnaire, car occupancy may be related to trip purposes, as Figure 4 shows. Going to or from work, or travelling while at work, was primarily done alone. Trips for shopping or transporting big items were mostly done alone or with another person. When visiting friends or relatives, it was more common to have additional passengers.



**Figure 4. Number of persons in the car, at respondents' most recent journey. Five persons in the car was very rare and is therefore not shown. The graph is based on data from the September questionnaire with 671 respondents.**

<sup>2</sup> Personal communication with City of Stockholm officials.

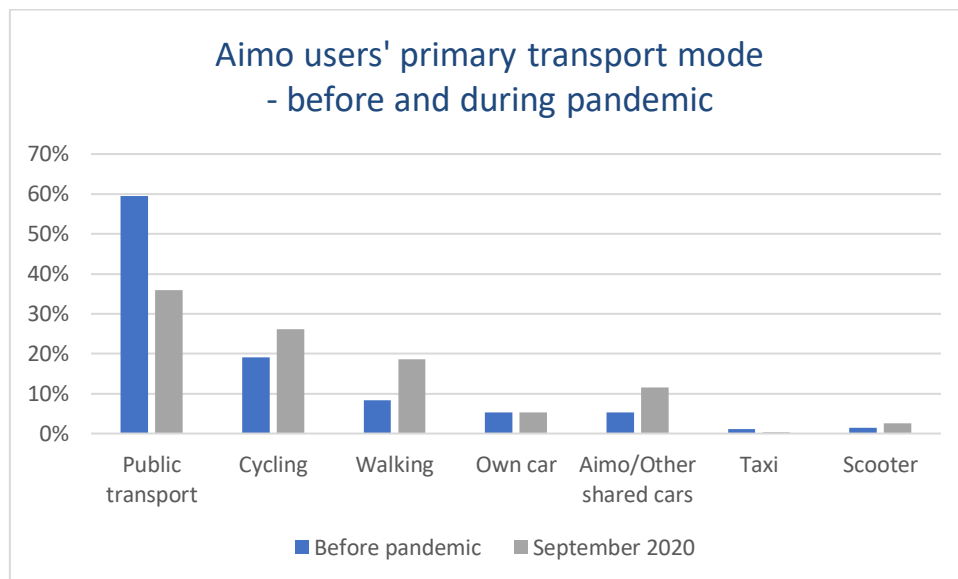


### 3.3 AIMO USERS' ALTERNATIVE TRANSPORT MODES

To understand how car-sharing can contribute to sustainable mobility, it is important to know what transport modes that are replaced by car-sharing. In the first questionnaire, respondents were asked what the alternative transport mode would have been, for their most recent Aimo trip. 60% answered 'public transport'. The interpretation and response to this question was discussed at length in the follow-up phone interviews. It turns out that it could be interpreted and answered in different ways, and that many respondents likely did not find that they could give a satisfactory answer.

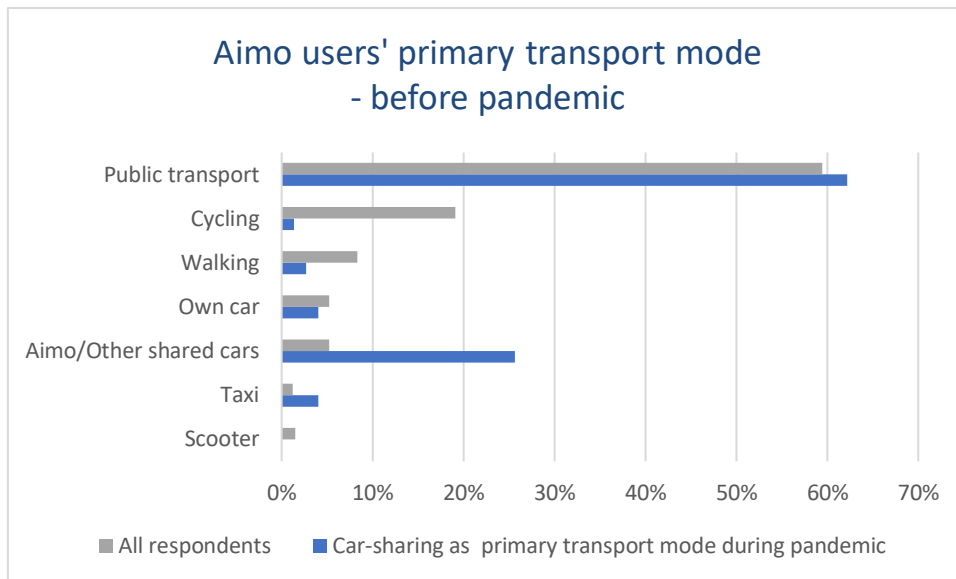
In the phone interviews, the respondents explained that they generally considered public transport to be their main transport mode, but that they would use Aimo cars when public transport was inaccessible. For example, they would use an Aimo car when visiting friends living in an area not served by public transport, or when travelling late at night when public transport is not operating. They would also use Aimo cars when public transport would be too impractical. For example, if they were carrying heavy grocery bags, or taking an elderly relative somewhere, or going to a destination which would have required multiple changes with public transport. In general, they would however use public transport, and that was how they responded in the questionnaire. Public transport might however not have been a realistic alternative for the trip in question.

The second questionnaire was redesigned, and respondents were instead asked to state their primary transport mode. Given that this questionnaire was distributed during the corona pandemic, when normal transport patterns were disrupted, the respondents were asked about their primary transport mode at the time of the questionnaire and before the pandemic. The results are presented in Figure 5. A majority, 59%, stated that before the pandemic, they had mainly travelled by public transport.



**Figure 5. Respondents' primary transport mode before the pandemic and in September 2020. The graph is based on data from the September questionnaire with 671 respondents.**

In the second questionnaire, 11% of respondents stated that they considered Aimo or other car-sharing services to be their current primary transport mode. As a group, they differ from the whole group of respondents in that they were more frequent Aimo users even before the pandemic. This is illustrated in Figure 6.



**Figure 6. Respondents' primary transport mode before the corona pandemic. The graph is based on data from the September questionnaire with 671 respondents, of which a subset of 74 mainly travel in shared cars during the pandemic.**

### 3.4 PICKING UP AND LEAVING AIMO CARS

In both questionnaires, respondents were asked where they had picked up and left their Aimo car – on-street or in a parking garage. They were also asked which option they preferred, if any. The results are presented in Table 4. In the phone interviews, respondents were asked to elaborate on their stated preference. In general, they preferred on-street parking not because they particularly liked to park in such an environment, but because it was closer to their home and/or their destination. They did not dislike the parking garages where Aimo cars may be parked but claimed that these garages were often too far off. However, a couple of respondents mentioned that in preparation for a longer trip they might specifically seek out an Aimo car in a parking garage. As the Aimo cars are often charged there, the chance of getting a fully charged car would be higher.

**Table 4. Respondents' pick-up and drop-off parking spots, and their preferred Aimo car parking, for both questionnaires.**

	February/March			September		
	Pick-up	Drop-off	Preference	Pick-up	Drop-off	Preference
<b>On-street</b>	94%	95%	63%	94%	95%	68%
<b>Garage</b>	6%	5%	5%	6%	5%	3%
<b>No preference</b>	n/a	n/a	31%	n/a	n/a	29%

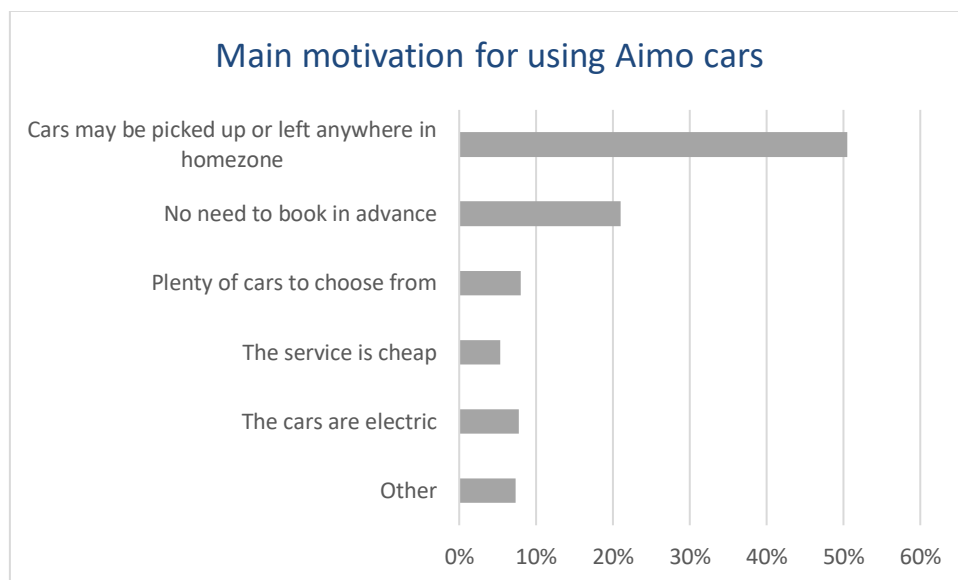
In the second questionnaire, respondents were asked how far they usually walk to pick up an Aimo car. The results are presented in Table 5. Most Aimo users walk between 200 and 500 metres to pick up a car. In the group of frequent Aimo users, a larger share generally walk less than 200 metres.

**Table 5. Respondent's general walking distance to pick up an Aimo car, based on data from the September questionnaire.**

Distance	All respondents (n=671)	Shared cars as primary transport mode during pandemic (n=74)
Less than 200 metres	23%	30%
Between 200 and 500 metres	62%	64%
More than 500 metres	14%	7%

### 3.5 MOTIVATION FOR USING AIMO

In the phone interviews, respondents were asked what makes them choose to use Aimo cars. They emphasised convenience; being able to get access to a car swiftly and spontaneously. Many also commented on the low costs, compared to having one's own car. A third reason that they gave is environmental friendliness, regarding not having to own a car and being able to drive emission-free. This question was then incorporated in the September questionnaire, in which respondents could choose between some pre-defined answers or select 'other' and describe their motivation. The results are presented in Figure 7. The convenience of free-floating shared cars, with the freedom to park anywhere (within certain limits), is clearly the most treasured feature.



**Figure 7. Respondents' main motivations for using Aimo services. The graph is based on data from the September questionnaire with 671 respondents.**

In the group of frequent Aimo users, who consider car-sharing to be their primary transport mode, the importance of the freedom to park anywhere is even more pronounced. 68% of frequent Aimo users stated that being able to pick up or leave a car anywhere in the homezone is the main reason why they use Aimo cars, to be compared with 51% of all respondents.

## 3.6 PARKING AND CHARGING

To understand how parking and charging are (or could be) managed, an interview with Aimo representatives and a workshop with City of Stockholm officials were performed. Through these, some parking and charging issues are illuminated.

### 3.6.1 Aimo's operation

Aimo utilises two types of parking: hotspots, i.e., parking spots reserved for Aimo cars, and on-street 24-hour parking spots for which regular parking regulations apply. Charging is often available at hotspots, but not at the on-street parking spots. To keep the Aimo fleet charged, Aimo staff pick up cars with low battery level from on-street parking and drive them to a hotspot with charging infrastructure. Then, they take fully charged cars back to the street, to replace the cars that were removed. Aimo staff also relocate cars that are at risk of getting a parking ticket to appropriate parking spots.

### 3.6.2 Public charging

Public charging infrastructure has grown rapidly in City of Stockholm, where the opportunity for charging providers to install public chargers in on-street parking spots has been established. The City owns the land, and maintains the parking spots, but charging providers may install and maintain chargers. There are slow and semi-fast public chargers in this network. At night, parking in a charging spot is allowed for twelve hours, but during the day, only three-hour parking is allowed. The semi-fast chargers are used more, indicating that faster charging is more attractive.

### 3.6.3 Different priorities

For a car-sharing provider, *access to fast charging and long-term parking is desirable*. The less time that is spent charging, the more the car is available for use. The more long-term parking, the less the need to move cars that have not been in use for a certain period of time.

For Aimo's customers, *proximity is essential*. On-street parking is generally preferred, as hotspots in parking garages are often too far away from customers' homes or destinations. Charging is often not an issue: in the phone interviews, respondents generally said that they travel short distances and that a range of 20 km will most often suffice. When heading out on a longer trip, Aimo users will find a fully charged car using the app.

For charging providers, *high customer turnover is desirable*. With limited parking time, more customers may use the parking spot and pay for charging. However, the charger needs to be fast enough to make it worthwhile for the customer to park and connect to the charger.

## 4 CONCLUDING DISCUSSION

Car-sharing is meant to increase sustainability, by reducing the number of cars and transforming the idea of mobility. The results from this study confirm that car-sharing can indeed contribute to sustainability. In the case of Aimo cars, car occupancy is higher than in passenger cars in Stockholm in general. The collected data shows that Aimo users tend to use public transport to a large extent. There are also indications that Aimo complements public transport; that Aimo cars are used when public transport is inaccessible or impractical. Thus, it would seem that free-floating shared cars are used when the customers have need for a car but not when other mobility options will suffice. That free-floating car-sharing complements public transport has been shown in previous studies (Ceccato and Diana, 2018; Silvestri et al., In Press).

Aimo's main attractiveness rests in the convenience of the services; that cars may be picked up and left anywhere within the homezone and that they do not need to be pre-booked. The results from this study show that the free-floating aspect is the main reason for using Aimo cars. This is even more pronounced for the group who consider shared cars to be their primary transport mode. Previous studies have also shown that convenience is an important motivation, and that free-floating adds to the attraction of car-sharing (Acheampong and Siiba, 2019; Rotaris et al., 2019; Silvestri et al., In Press).

This study indicates that free-floating shared electric cars can be an important part of sustainable urban mobility. Facilitating free-floating shared electric cars is however not a simple task. Parking and charging are at the core of the concept, and different actors have different requirements on these aspects. To keep the attractiveness of the free-floating operation, a multitude of potential parking spaces, located all over town, is important for the car-sharing customers. From the point of view of the car-sharing provider, these parking spaces need to allow parking for a fairly long period of time, to ensure that the car gets picked up by the next customer before getting a parking ticket. Both the customer and the provider are interested in fast charging, as that means that charging cars are unavailable only for a short period. The charging provider is also interested in fast charging, as it allows for more customers to charge in a day. To enable more customers, limited parking time is however important, so that fully charged cars do not block charging spaces. This equation is difficult to solve.

Parking is usually regulated in detailed development plans, in which the purposes of the urban space are defined. Charging is generally not included in the detailed development plans, as that would make the plans too specific with regard to a certain technology. On public land, parking regulations shall be equivalent regardless of vehicles and owners. Shared cars cannot get any benefits. On private land, the property owner decides what regulations apply, and parking spaces may for instance be reserved for shared cars. Thus, with current regulations, on-street parking spaces that are popular among Aimo customers can for instance not be reserved for shared cars or have different costs for car-sharing operators. Such schemes could be created and used by property owners, who could create car-sharing hotspots and install dedicated chargers. This might facilitate car-sharing, but as this study has shown, free-floating and on-street parking are important aspects for the attractivity of this mobility service. Collaboration and consideration are needed, to create successful car-sharing incentives. Urban planning to facilitate car-sharing and electric cars should be studied further, as this is probably one of the keys to sustainable urban mobility.

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## APPENDIX A

### Questions and response alternatives in the February/March questionnaire

Q1: Was your most recent Aimo trip made privately or at work?

- Privately
- At work

Q2<sup>3</sup>: What was the purpose of your most recent Aimo trip? (E.g., seeing friends or going shopping.) Please describe.

Q3: If you had not used Aimo, what would have been the alternative transport mode for this trip?

- Public transport
- Cycling
- Walking
- Own car
- Rental car
- Taxi
- Scooter

Q4: Did you travel alone?

- Yes
- No

Q5<sup>4</sup>: How many people travelled in the car, in total?

- 2
- 3
- 4
- 5

Q6: Did you have cargo? (E.g., suitcases, grocery bags, furniture, or other big items.)

- Yes
- No

Q7: Where did you pick up the car?

- On-street parking
- Parking garage

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<sup>3</sup> Not applicable if answer to Q1 was At work.

<sup>4</sup> Not applicable if answer to Q4 was Yes.

Q8: Where did you leave the car?

- On-street parking
- Parking garage

Q9: Where do you prefer to pick up/leave the Aimo car?

- On-street parking
- Parking garage
- Does not matter

Q10: Do you have any comments on Aimo's role in the Stockholm city traffic? Please describe.

Q11: Would you care to be contacted by a researcher to answer additional questions about your experience using Aimo?

- Yes (please leave contact details below)
- No



## **APPENDIX B**

### **Structure of phone interviews following up on the February/March questionnaire**

The phone interviews started by a recap of what the respondent had stated in the questionnaire, about a certain Aimo trip. Then, the interviewer explained that the additional questions would be more generally about the respondent's use of Aimo services.

Q1: How often do you generally use Aimo?

Q2: What purposes do you generally have when using Aimo?

Q3: What is generally the alternative transport mode when you use an Aimo car?

Q4: With regard to where you prefer to pick up and leave Aimo cars, what is the reason for your preference?

Q5: Do you usually check the car's remaining range when you take an Aimo?

Q6: Is the car's remaining range generally sufficient for your trip?

Q7: Have you ever charged an Aimo car, for your own needs or as a service to the next customer?

Q8: What is your primary mode of transport?

Q9: Do you own a car?

Q10: How convenient do you find Aimo services?

## APPENDIX C

### Questions and response alternatives in the September questionnaire

Q1: Was your most recent Aimo trip made privately or at work?

- Privately
- At work

Q2<sup>5</sup>: What was the purpose of your most recent Aimo trip? (E.g., seeing friends or going shopping.)

- Going to or from shops
- Seeing friends or relatives
- Going to or from work
- Transporting big or heavy items
- Other (please describe)

Q3: Did you travel alone?

- Yes
- No

Q4<sup>6</sup>: How many people travelled in the car, in total?

- 2
- 3
- 4
- 5

Q5: Did you have cargo? (E.g., suitcases, grocery bags, furniture, or other big items.)

- Yes
- No

Q6: Where did you pick up the car?

- On-street parking
- Parking garage

Q7: Where did you leave the car?

- On-street parking
- Parking garage

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<sup>5</sup> Not applicable if answer to Q1 was At work.

<sup>6</sup> Not applicable if answer to Q3 was Yes.

Q8: Where do you prefer to pick up/leave the Aimo car?

- On-street parking
- Parking garage
- Does not matter

Q9: How far do you usually walk to pick up an Aimo car?

- Less than 200 metres
- Between 200 and 500 metres
- More than 500 metres

Q10: What is your main reason for using Aimo?

- Picking up and leaving the car anywhere within homezone
- Not having to book in advance
- Plenty of cars to choose from
- The cars are electric
- The service is cheap
- Other (please describe)

Q11: Did you use Aimo before the corona pandemic?

- Yes
- No

Q12: Before the corona pandemic, what was your primary mode of transport?

- Public transport
- Cycling
- Walking
- Own car
- Aimo or other shared cars
- Taxi
- Scooter

Q13: Currently, what is your primary mode of transport?

- Public transport
- Cycling
- Walking
- Own car
- Aimo or other shared cars
- Taxi
- Scooter