# The impact of low-car residential neighbourhoods on mobility behaviour

## A case study of Cartesius in Utrecht from residents' perspectives

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## A case study of Cartesius in Utrecht from residents' perspectives

by

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# Summary

Urban densification is a growing challenge in cities worldwide, with increasing pressure on limited space. As cities become more compact, maintaining liveability and accessibility while accommodating growth becomes increasingly difficult. Cars take up a lot of this valuable space, both in terms of parking and infrastructure. At the same time, private car use contributes significantly to environmental issues and urban congestion. Low-car residential developments are an emerging strategy to address these challenges, aiming to reduce car dependency through urban design and policy measures. However, much of the existing research on low-car neighbourhoods focuses on cases where residents actively chose such an environment. This raises an important question: what happens when people who did not intentionally select a low-car area move into such a neighbourhood? With large numbers of housing developments being built within cities, a more diverse range of residents will inhabit these areas, including many who may not have initially sought a car-free lifestyle. Understanding whether non-self-selected residents also adjust their mobility habits provides insights into the effectiveness of low-car policies. Which is essential for evaluating the viability of these developments.

This study addresses this research gap by taking a revealed preference approach to investigate how residents of low-car neighbourhoods perceive and adapt to sustainable mobility measures, and how their adaptation is influenced by residential self-selection. The main research question guiding this study is:

> *How do residents of low-car neighbourhoods **perceive** and **adapt** to the sustainable mobility measures, and how is this influenced by **residential self-selection**?*

This research separates behaviour changes driven by the built environment from those stemming from pre-existing preferences by distinguishing between self-selected and non-self-selected residents. If even non-self-selected residents adapt their behaviour in line with the goals of a low-car neighbourhood, this provides stronger evidence that the built environment itself can influence travel behaviour beyond individual attitudes.

The research is based on a case study of Cartesius, a newly developed low-car neighbourhood in Utrecht with 322 households. Cartesius offers a unique opportunity to study residents in a real-world example of a dense urban low-car neighbourhood, providing insight into the lived experience of residents. The study employed a survey (N=70) and informal conversations with residents to examine their mobility behaviour, attitudes, and experiences.

### Results

Survey results showed that, since moving to Cartesius, residents' public transport use and shared car adoption increased, while car use and ownership declined. Specifically, 20% of previous car owners disposed of their vehicle, and an additional 13% were considering doing so. Every respondent who got rid of their car mentioned the limited parking spaces as the primary reason, highlighting the effectiveness of parking policies in reducing car ownership. However, overall satisfaction with mobility in the neighbourhood was low. More than half of all respondents stated that the neighbourhood did not meet their mobility needs. The dissatisfaction is largely attributed to temporary infrastructure issues, including a lack of pedestrian and cycling infrastructure and temporary unregulated parking in the public space. Notably, dissatisfaction with parking was reported equally by car owners and non-car owners. Also, in conversations with the residents, parking was a dominant subject, with annoyance widely shared. Frustrations do not solely stem from personal car use but also from issues such as visitor parking, enforcement of parking regulations, and unmet expectations about the car-free public area. Additionally, residents felt poorly informed about the mobility policies before moving in, with 30% reporting feeling insufficiently or incorrectly informed about the parking regulations. The study also found that incentives for alternative mobility can be effective. More than one third of the residents made use

of the free shared-car trip minutes offer, and many indicated that this encouraged them to use shared cars more frequently.

A crucial component of this research was examining the role of residential self-selection. This was done by dividing residents into self-selected and non-self-selected groups. The non-self-selected group was identified using two criteria: (1) residents who moved to Cartesius due to limited housing options rather than a preference for a low-car lifestyle, and (2) residents whose mobility behaviour and preferences did not align with the neighbourhood's low-car concept. A significant portion (57%) of residents in Cartesius fell into the non-self-selected category, highlighting the broader relevance of this study in the context of large-scale low-car developments. Many respondents explicitly stated they had no other housing options due to the housing shortage, with comments such as: "It was the only apartment I was assigned; if you decline, you're waiting another year." Others were identified as non-self-selected based on survey responses regarding mode preference, ideal living scenarios, and car use frequency, which revealed that their mobility patterns did not align with the neighbourhood's low-car concept. The survey responses of both groups are compared. Table 1 presents an overview, highlighting both notable contrasts and variables that show little to no difference. Key findings are discussed below.

| | Self-selected residents (N=30) | Non-self-selected residents (N=40) | Significance |
|---|---|---|---|
| **Mobility behaviour adaption after relocation** | | | |
| Percentage of car owners that have gotten rid of car or are considering it | 50% | 28% | ns |
| Percentage of people using more PT since moving | 23% | 35% | ns |
| Percentage of people using shared cars more often | 40% | 18% | p = 0,036 |
| Percentage of people who have reduced car use | 45% | 22% | ns |
| **Perception of neighbourhood's low-car concept and sustainable mobility measures** | | | |
| How content people are with living in Cartesius, and how well the neighbourhood meets their mobility needs | No difference | | |
| Satisfaction with parking spaces, accessibility by foot, accessibility cycling, availability of shared cars, access to train network | No difference | | |
| Percentage of people that feel well-informed about parking policy | 70% | 55% | p = 0,035 |
| **Socio-demographic characteristics** | | | |
| Percentage of car-free households | 80% car-free | 30% car-free | p < 0,001 |
| Socio-demographics (education level, age, gender, household composition) | No difference | | |
| Previous residential area | No difference | | |

**Table 1:** Comparison of groups of self-selected and non self-selected residents

In both groups, car ownership and car use declined, while public transport and shared car use increased. However, self-selected residents were significantly more likely to adopt shared cars as they were less likely to own a private vehicle. Self-selected residents were also significantly more likely to feel well-informed about the parking policy than non-self-selected residents. Satisfaction levels were similarly low across both groups, particularly concerning different mobility aspects. Interestingly, no socio-demographic differences were found between the groups, largely due to the homogeneous population living in Cartesius. Which consists of young, highly educated individuals without children. The

study also found no differences based on previous residential location, suggesting that mobility adaptation in the neighbourhood was not directly linked to where people had lived before.

## Conclusion

The study demonstrates that low-car neighbourhoods can facilitate sustainable mobility behaviours even among residents who did not initially choose this mobility concept. Despite not actively selecting a car-free environment, many non-self-selected residents adapted their behaviour in line with the neighbourhood's mobility measures, reducing car ownership and usage while increasing public transport and shared car use. This finding reinforces the idea that well-designed low-car policies can influence behaviour beyond self-selection effects, reinforcing their role as a strategy for managing space scarcity in dense cities while supporting more sustainable mobility patterns.

The research also highlights challenges that must be addressed. Overall satisfaction with mobility in Cartesius was low, largely due to temporary infrastructure issues and a lack of clear communication about mobility policies. Dissatisfaction was not confined to non-self-selected residents, indicating that negative perceptions were more related to implementation challenges than to the low-car concept itself. Issues such as incomplete infrastructure, temporary parking arrangements, and inadequate communication about mobility policies contributed to dissatisfaction. To improve future low-car developments, policymakers should prioritise clear communication with residents about mobility policies before move-in, actively manage temporary infrastructure to prevent early-stage dissatisfaction, and provide visible benefits from parking reductions.

Future research should build on these findings by conducting longitudinal studies to assess long-term behavioural adaptation and policy effectiveness over time. Additionally, research should expand to include a more diverse population, as the residents of Cartesius, while offering a valuable first step beyond traditionally self-selected low-car communities, still represent a relatively homogeneous group. Understanding how low-car policies affect a broader demographic will be key to scaling up these developments successfully.

Overall, this is promising news for the future of large-scale low-car developments. Despite possible dissatisfaction from the residents, low-car neighbourhoods can be effective in altering individual travel behaviour in a desired way, which is the central planning goal. If well-executed, these neighbourhoods have the potential to support sustainable mobility even among those who did not initially choose a car-free lifestyle.

# Contents

# 1

# Introduction

## 1.1. Background

Urbanisation is rapidly accelerating worldwide, with an estimated 55% of the global population already living in urban areas (United Nations 2023). This trend is expected to continue, placing immense pressure on cities to accommodate growing populations while maintaining quality of life. The demand for housing and services is driving densification, particularly in European cities where space is inherently scarce. This scarcity intensifies competition for land use, with private cars often dominating the urban landscape despite being stationary 96% of the time (Kennisinstituut voor Mobiliteitsbeleid 2022). The infrastructure for cars consumes up to 50% of public space in Dutch cities, and car users demand 3.5 times more physical space than non car users, underscoring the inequities imposed on the broader population by car dependence (Creutzig et al. 2020; Zijlstra, Witte, and Bakker 2022).

Beyond space constraints, private cars contribute significantly to environmental pressures. Their impact has been widely studied across various disciplines, with research highlighting their role in air pollution, greenhouse gas emissions, and urban heat effects (Banister 2008; EEA 2020; Seto, Güneralp, and Hutyra 2012; Newman and Kenworthy 1998). In dense urban areas, vehicles further contribute to congestion, noise pollution, and a reduction in green space — all of which undermine efforts to create safe, healthy, and liveable cities (Gehl 2013; Nieuwenhuijsen et al. 2019).

Despite these well-documented negative impacts, traditional policies have long prioritised private car use. The dominance of car-based planning has deep roots in what Urry (2004) and Manderscheid (2014) describe as the *system of automobility*, which historically structured urban environments around car use, embedding car dependency deeply into both city forms and behaviour. However, there is growing recognition that this approach is unsustainable. Over the past several decades, urban development has shifted, moving towards models that prioritise sustainability, liveability, and human-centred design (Jones 2014; Selzer and Lanzendorf 2019; Borges and Goldner 2015). Central to this transformation is the integration of land use and transportation planning, where streets and public spaces are reconceived as multifunctional areas serving communities rather than primarily facilitating vehicle traffic. As cities become denser, the need for innovative urban mobility solutions becomes clear. Reducing car dependency is increasingly seen as essential not only for environmental sustainability but also for reclaiming urban space for people (Selzer 2021; Borges and Goldner 2015; Müller and Reutter 2022).

This shift is best captured by former Bogotá mayor Enrique Peñalosa, who stated:

> *'The first step to reducing car dependency is designing our streets as though people matter more than vehicles.'*
>
> — Enrique Peñalosa, former mayor of Bogotá, Colombia

### 1.1.1. The emergence of low-car, high-density neighbourhoods

In response to the growing challenges of urbanisation, climate change, and space scarcity, cities are increasingly adopting new approaches to urban mobility and land use. Low-car, high-density neighbourhoods are emerging as a key strategy to accommodate urban growth while reducing car dependency. Unlike traditional car-free areas—often shaped by historical, cultural, or geographical constraints (Melia 2009; Nies 2020)—modern low-car developments are intentionally designed to prioritise active and public transport. These neighbourhoods integrate mobility strategies that discourage private car use while aiming to enhancing accessibility and quality of life.

By limiting or excluding private cars, these developments promote a shift toward sustainable mobility patterns and reclaim urban space for alternative uses, such as parks, pedestrian zones, and social spaces. Research highlights several benefits of this model, including improved air quality, reduced noise pollution, improved safety, and greater community engagement (Borges and Goldner 2015; Gehl 2013; Nieuwenhuijsen et al. 2019). They also contribute to public health by encouraging active travel modes such as walking and cycling. Given these benefits, it is tempting to view low-car neighbourhoods as a comprehensive solution to urban mobility challenges.

However, transitioning to low-car urban living presents significant challenges. The success of these neighbourhoods depends not only on their physical design but also on how residents perceive and adapt to mobility restrictions (Nieuwenhuijsen et al. 2019). This is particularly relevant given that most people do not want to give up their cars or be restricted in parking. The car remains a highly convenient and flexible mobility option, and the removal or restriction of cars cannot be done without careful consideration. Studies by Borgers et al. (2008) and Borges and Goldner (2015) indicate that the majority of residents of four Dutch cities prefer to live in areas without car restrictions. Despite these preferences, large-scale urban low-car developments are rapidly emerging, reflecting a broader shift in urban planning (Baehler and Rérat 2022; Kuss and Nicholas 2022). Driven by the need to build more housing within cities while maintaining liveability and accessibility, policymakers and urban planners increasingly conclude that there is little to no room for private vehicles in these new developments.

This highlights a potential misalignment: car-reduced housing being developed, but no residents wanting to reduce cars. One could simply say that these low-car neighbourhoods will then be inhabited by people that do want to reduce cars. Which is what has happened in the past, where car-free communities and neighbourhoods can be observed across Europe. People that want to live car-free find the right circumstances to do so in these areas. This alignment of people's residential location and their travel preferences is the concept of residential self-selection. People usually choose a neighbourhood that fits their travel pattern. But with the pressing challenges of cities, low-car neighbourhoods might outgrow their status of niche residential places for people that support the concept. Large-scale developments are planned, often with mixed housing options, including rental and social housing. In these cases, residents may not have the luxury of choosing a neighbourhood based on their preferences, which could create challenges in adapting to low-car environments. The growing pressure on the housing market, especially in larger cities across the Netherlands, makes securing housing a higher priority than finding an ideal living situation.

As low-car neighbourhoods are increasingly being developed, understanding their impact becomes crucial. These developments have the potential to contribute to more liveable, accessible, and sustainable cities, but much remains uncertain about their broader applicability and success. While transportation models can offer projections, the actual impact on residents' mobility behaviours and quality of life is still to be fully understood. This thesis aims to contribute to the understanding of how people experience and adapt to living in such environments, focusing on the human dimension of low-car neighbourhoods, rather than just their spatial and environmental impacts.

## 1.2. Utrecht context

Utrecht offers a pertinent example of a city actively addressing the challenges of densification and car dependency. As one of the largest cities in the Netherlands, Utrecht is experiencing significant population growth and has ambitious plans to build thousands of new homes in the coming years. However, this growth comes with the challenge of maintaining the city's liveability amidst limited space and high density. The city has already taken steps to address these challenges through various initiatives aimed

at reducing car usage. These include the implementation of low parking norms and the expansion of cycling infrastructure, a key component of Utrecht's mobility strategy.

One of the city's most notable projects is the Merwedekanaalzone, which will involve the development of a low-car residential area for approximately 10,000 residents. This project is still in the planning stages, but it highlights Utrecht's commitment to reducing car dependency on a large scale.

Utrecht's efforts to reduce car usage, coupled with its need for more housing, make it a fitting context for exploring the potential of low-car urban environments. While the Merwedekanaalzone is not yet developed and inhabited, Utrecht offers other examples of low-car and high-density urban areas. Neighbourhoods such as Wisselspoor and Cartesius, while smaller in scale, already feature low parking norms, shared mobility options, and a focus on walking and cycling. Studying these areas can provide valuable insights into the real-world effects of such strategies.

## 1.3. Research gap

There is limited research on how residents with no initial intention of living without cars adapt to low-car neighbourhoods, a key gap this research aims to address. With large numbers of housing developments being built within cities, a more diverse range of residents will inhabit these areas, including many who may not have initially sought a car-free lifestyle. Much of the existing research is limited to eco-villages or communities where residents already embrace car-free living, failing to capture the experiences of diverse populations (Selzer and Lanzendorf 2022). Future projects will attract a broader population, not just those with pre-existing low-car lifestyles, making it essential to evaluate the effects on a larger scale (Sprei et al. 2020).

Additionally, many studies on existing low-car neighbourhoods focus on best-practice examples, often overlooking the complexities and challenges faced by residents in their daily lives (Freytag et al., 2013). Marsden (2006) stress that evaluations based on observed behaviours, rather than stated preferences, are crucial for understanding the real impact of low-car policies. With many studies relying on stated preference data rather than observed behaviours, this leaves a need for ex-post evaluations to assess the real impact of low-car policies. Understanding these lived experiences is crucial to find out if dense, low-car urban areas can truly reduce car dependency, promote alternative transport modes, and maintain high levels of accessibility and liveability for residents. Minimal research exists on how low-car developments influence mobility patterns or on the preferences of residents in Dutch low-car areas (Nieuwenhuijsen et al. 2019). The availability of revealed preference data, observing actual behaviours and patterns in real-world contexts, remains scarce. But looking at this from a residents perspective is really important (Dijk, Givoni, and Diederiks 2018; Kuss and Nicholas 2022). Many different studies highlight this, with Nieuwenhuijsen et al. (2019) calling for in-depth assessments of residents' experiences, and Selzer and Lanzendorf (2019) stressing the importance of looking at residents' lived practices to assess the real-life impact of such developments.

With the most important knowledge gap remaining: what happens when people who did not actively choose to live in a low-car environment move to such an area, particularly in the context of large-scale low-car developments attracting diverse populations. To the best of the author's knowledge, this aspect has yet to be thoroughly investigated.

## 1.4. Research objective and questions

Drawing from the problem definition of limited knowledge about the effects and implications of mobility strategies on residents in low-car neighbourhoods, this study seeks to make a contribution by evaluating these developments. The main objective of this research is to gain insights into how residents in low-car neighbourhoods experience and adapt to the mobility strategies implemented in these areas.

Using a case study approach, the research draws on the experiences of current residents to provide lessons for future low-car developments, both within Utrecht and globally. The ultimate aim is to support the transition towards sustainable liveable cities by offering insights for the design and implementation of neighbourhoods that reduce car dependency.

The research aim is translated into a main research question and additional sub-questions. The main research question is formulated as follows:

> *How do residents of low-car neighbourhoods **perceive** and **adapt** to the sustainable mobility measures, and how is this influenced by residential self-selection?*

Sub-questions are formulated to approach the main research question step by step. The sub-questions focus on the proposed neighbourhood for the case study: Cartesius.

1. *What factors shape residents' perceptions of a low-car neighbourhood?*
   This question involves both a theoretical and empirical component. First, a literature review is conducted to identify factors that influence residents' perceptions of low-car neighbourhoods. This includes examining behavioural studies and evaluating findings from similar low-car neighbourhoods in different contexts. By identifying common factors that shape perceptions, the study creates a foundation for understanding these dynamics. The findings from the case study of Cartesius then supplement this theoretical base, providing insights into the specific factors that influence residents' perceptions in this context.
2. *Who are the residents of low-car neighbourhoods in terms of socio-demographics, attitudes, and travel behaviour, and how do these compare to residents of other neighbourhoods?*
   This question aims to profile the residents of low-car neighbourhoods, combining insights from both literature and the case study of Cartesius. The literature review examines socio-demographic characteristics, attitudes, and travel behaviour patterns commonly observed among residents of low-car neighbourhoods. Subsequently, the characteristics and behaviours of Cartesius residents are analysed and compared with these broader findings and with residents from other neighbourhoods. This dual approach provides insights into the role of residential self-selection and helps to better understand the practical implications of low-car neighbourhoods in different contexts.
3. *What mobility strategies or policy measures have been implemented in Cartesius to create the low-car residential area, and how effective are they?*
   This question seeks to identify and evaluate the specific strategies and policy measures implemented in Cartesius to create a low-car environment. The first step is to document the measures adopted, such as parking restrictions, shared mobility services, and infrastructure for active modes of transport. After establishing this foundation, the study assesses the effectiveness of these measures by examining residents' experiences and travel behaviour. Understanding which strategies have been successful and which have encountered challenges provides valuable lessons for the design and implementation of similar future developments.
4. *How do residents of Cartesius perceive mobility options and the implemented car-reducing policy measures?*
   This question focuses on understanding residents' perspectives regarding the available mobility options and the car-reducing measures implemented in Cartesius. While models and policy documents can provide objective data on accessibility and modal options, only residents' perceptions can reveal how these measures are experienced in everyday life. The findings help to identify strengths and weaknesses in the mobility concept and offer insights into the factors contributing to a positive or negative perception of the neighbourhood's car-free design.
5. *Has the mobility behaviour of residents of Cartesius changed since moving, and how do their current mobility patterns compare to their previous habits?*
   Understanding whether living in a low-car neighbourhood has led to changes in residents' travel behaviour is key to evaluating its impact.
6. *What lessons can be drawn from residents' experiences to inform the implementation of future low-car developments?*
   This question aims to derive practical insights from the case study. It provides concrete recommendations for the municipality of Utrecht, aligning with their main objective: to apply these lessons to guide and improve larger upcoming developments.

Including residential self-selection in the analysis is essential to distinguish between behaviour changes driven by the built environment and those resulting from residents' pre-existing preferences. Under-

standing the presence of non-self-selected residents, those who did not actively choose Cartesius for its mobility concept, is particularly important for evaluating the effectiveness of the low-car policy and the effect of residential self-selection.

## 1.5. Report structure

This report is structured as follows: Chapter 2 outlines the methodology, linking the research methods to the sub-research questions and explaining the methods used. Chapter 3 presents the literature study, addressing some of the sub-research questions directly and providing the theoretical foundation for the case study and the overall research. Chapter 4 introduces the case study area, Cartesius, describing the neighbourhood, its socio-demographic characteristics, and the local mobility framework. Chapter 5 presents the data analysis and results of the case study. Chapter 6 provides the conclusion by answering the main research question and outlining policy recommendations. Chapter 7 concludes the report by providing a discussion of the findings, ending with recommendations for future research.

# 2

# Methodology

## 2.1. Project approach

The core of the project consisted of a case study of the low-car neighbourhood Cartesius. The main component for data gathering was a survey among residents. Besides a residents survey, familiarity with the case was also gained through on-site observations, talking to different people from the municipality and other organisations involved in the neighbourhood, as well as informal conversations with residents.

The research was guided by a theoretical background developed through a literature review. This review explored various car-reduced neighbourhood concepts and the policy measures used to achieve them. It examined the complex relationship between travel behaviour, the built environment, and personal attitudes and characteristics. A key focus was on how low-car policy measures are perceived by residents and the factors that shape these perceptions. Additionally, significant attention was given to case studies of other low-car neighbourhoods, providing insights into residents' behaviour and characteristics. The findings from the survey, combined with insights from the literature, informed the answers to the research questions and ultimately shaped the conclusions and policy recommendations.

Table 2.1 gives an overview of the sub-questions and methods used for answering them.

| Sub-question | Corresponding method | Chapter |
|---|---|---|
| 1. What factors shape residents' perceptions of a low-car neighbourhood? | **Literature review** of travel behaviour studies and case examples of low-car neighbourhoods | Chapter 3 |
| | Supplemented by **survey data and conversations with residents** from the Cartesius case study | Chapter 5 |
| 2. Who are the residents of low-car neighbourhoods in terms of socio-demographics, attitudes, and travel behaviour, and how do these compare to residents of other neighbourhoods? | **Literature review** of existing low-car neighbourhood case studies to examine resident profiles and mobility patterns | Chapter 3 |
| | **Cartesius case study:** Analysis of socio-demographic data from the Municipality of Utrecht, and insights into residents' attitudes and travel behaviour obtained through the **survey and conversations with residents** | Chapter 4, 5 |
| 3. What mobility strategies/policy measures have been implemented in Cartesius to create the low-car residential area, and how effective are they? | **Case study analysis** through on-site observations, meetings with municipal stakeholders involved in Cartesius, and evaluation of policy documents | Chapter 4 |
| | **Survey and conversations with residents** to assess the perceived effectiveness of the implemented measures | Chapter 5 |
| 4. How do residents of Cartesius perceive mobility options and the implemented strategy/policy? | **Survey questions** on resident satisfaction with various mobility aspects, complemented by **conversations with residents** to gather more detailed perceptions and experiences. | Chapter 5 |
| 5. Has the mobility behaviour of residents of Cartesius changed since moving, and how do their current mobility patterns compare to their previous habits? | **Survey questions** comparing residents' travel behaviour before and after relocation to Cartesius | Chapter 5 |
| 6. What lessons can be drawn from residents' experiences to inform the implementation of future low-car developments? | **Synthesis of findings** from the literature review, survey results, and case study to derive practical recommendations | Chapter 6, 7 |

**Table 2.1:** Sub-questions and corresponding methods and chapters

## 2.2. Contextual meetings and expert input

At an early stage of the thesis, interviews with experts were conducted to guide the research direction and inform the selection of suitable methods. These interviews contributed to the development of the survey questions for residents. The participants included employees from the municipality of Utrecht involved in the policy development of car-free neighbourhoods, as well as specialists in mobility concepts related to the car-free mobility strategy, such as professionals from the Parking department. These discussions also provided an introduction to the cases of Wisselspoor and Cartesius and offered preliminary insights into how the municipality approaches the implementation of such projects. Wisselspoor was initially explored as a case study area as well, but later omitted. Practical advice on reaching and engaging residents for the study was another topic addressed in these meetings. These interactions, while often informal and open-ended, complemented desk research and offered a practical perspective. Table 2.2 gives an overview of the meetings and type of takeaways.

| Date | Function Title | Expertise | Summary | Knowledge Obtained |
|---|---|---|---|---|
| 04-10 | Policy Advisor/ Project Manager - Mobility Strategy | Mobility concept, Cartesius planning | Cycling tour highlighting parking issues in Cartesius and differences with Wisselspoor. | Case selection + general knowledge on low-car mobility strategies |
| 04-10 | Resident of Cartesius | Broad Mobility Affairs trainee at municipality | Shared residents' issues and provided practical help for case study access. | Case selection + case insights + practical tips |
| 23-10 | Strategic Project Manager | Wisselspoor project | Tour of Wisselspoor, shared car arrangements, history/evaluation. | Wisselspoor experience + shared car knowledge |
| 31-10 | Policy Advisor/Project Manager - Parking | Parking strategy, shared cars | Explained various parking strategies in Utrecht, including car-sharing. | Knowledge on parking concepts and strategies |
| 12-11 | Advisor for Healthy Living Environment | Cartesius living lab, healthy urban living | Discussed Cartesius as a living lab and Blue Zone with focus on healthy living. | Case background information |
| 27-11 | Community Advisor | Community manager Cartesius | Shared insights on engaging with residents, invited to community activity. | Case insights + practical tips |
| 12-12 | Neighbourhood Advisor | Wisselspoor, resident interactions | Explained municipal-resident interactions, common complaints, and initiatives. | General municipal-resident interaction knowledge + practical tips |
| 09-01 | Hospitality Business Owner | Wisselspoor business and planning | Shared experiences working with municipality during planning phase. | Wisselspoor experience + business perspective |
| 15-01 | Community Advisor | Wisselspoor and surrounding areas | Discussed parking problems caused by Wisselspoor residents. | Wisselspoor experience |
| – | Policy Advisors/Project Managers - Broad Mobility Affairs | Mobility data | Provided information on available data and Utrecht's resident survey. | Data availability insights |

**Table 2.2:** Overview of contextual meetings and takeaways

Besides the meetings listed in Table 2.2, being an intern at the municipality Utrecht involved participation in various organisational activities. Many colleagues expressed interest in the research, leading to valuable discussions. Participation in different project meetings provided additional insights into ongoing work. Attending internal meetings also offered a deeper understanding of planning processes, decision-making structures, and the translation of broader strategies and visions into tangible projects. These experiences contributed to a better understanding of the context in which the municipality operates.

## 2.3. Literature review

### 2.3.1. Goal of the literature study

The literature review aimed to explore existing low-car concepts and developments to understand how they operate. This review also helped identify gaps in the existing knowledge. Specifically, whether and how low-car neighbourhoods have been evaluated, and from which perspective. In addition to creating an overview of the state of the art knowledge on low-car developments and finding knowledge gaps, the literature review directly informed the main research question and some of the sub-questions.

The first sub-question concerns what factors shape residents' perceptions of a low-car neighbourhood. To address this, the review explored how various car-reducing policies and measures are perceived by residents. The literature provided an overview of different low-car measures and their reception by residents in various contexts. Additionally, through analysing previous low-car development case studies, it identified key aspects that can contribute to the success of low-car neighbourhood.

The second sub-question examines who the residents of low-car neighbourhoods are. To address this the literature review looked into case studies of existing low-car neighbourhoods, focusing on the profiles of their residents.

The fourth and fifth sub-question explore how people's mobility patterns have changed since moving to Cartesius and residents' perception of the neighbourhood. These questions were not directly addressed through the literature review. But a theoretical foundation for understanding how travel behaviour evolves in response to relocation was built through literature findings. It looked at how travel behaviour, attitudes, and the built environment interact to shape residents' mobility patterns, providing insight into the factors contributing to the success or challenges of such measures. Finally, the literature review examined the role of residential self-selection: How do the residents of low-car neighbourhoods select their residences, and how does this influence their travel behaviour? The review looked into the theory of self-selection and investigated whether this factor has been considered in other case studies.

### 2.3.2. Literature search method

A variety of sources was used for conducting the literature search. First, the TU Delft repository was consulted, as car-free cities are a popular research topic and previous student work may provide useful insights. Grey literature, such as conference proceedings and governmental reports, were also reviewed to understand the current situation and historical context of car-free developments both globally and in the Netherlands. Scientific databases like Scopus and Google Scholar were also utilised to find peer-reviewed literature, with keyword searches serving as the primary search strategy. In addition to traditional keyword searches, snowballing techniques were employed, encompassing both backward and forward snowballing, whereby relevant publications were identified through references and citations. Table 2.3 presents the overview of used search terms divided into different categories.

| **Category** | **Keywords** |
|---|---|
| Core concept in different forms of writing | *carfree, car-free, low-car, car-low, car reduc*, car-light, car-lite* |
| Spatial scope | *neighbourhood*, residential area*, housing, city, cities, district, developments, Netherlands, Dutch, Europe* |
| Case study | *case study, evaluat*, analys*, case, implement** |
| Parking | *parking management, parking norm, limit** |
| Residential self-selection | *self-selection, self selection, built environment, relocation* |
| Attitudes and preferences | *attitude*, behaviour, preference*, choice, stated, motivations* |
| Evaluation | *challenge*, benefit*, percept*, perceiv*, impact, effect*, indicator, aspect, factor, success, …* |
| Travel behaviour | *travel behaviour, travel pattern*, practice*, car use, car usage, car owner** |
| Examples: a specific search for more case studies or evaluations of the found car-reduced examples | *Vauban, Florisdorf, Groot Merwede, Merwedekanaalzone, Cartesius Utrecht, Wisselspoor Utrecht, GWL* |
| Dutch search terms | *autoluw, autovrij, auto arm, parkeernorm** |

**Table 2.3:** Literature search topics and keywords

The core concept was initially used as a search term. Keywords from other categories, such as spatial scope, case study, and evaluation, were then combined with the core concept using AND. The

literature search uncovered important case study areas, such as Vauban and Florisdorf. A specific search on these low-car neighbourhood examples was also conducted, including the case of Groot Merwede/Merwedekanaalzone. Only the most prominent case studies searched for are listed in the table; however, this is not exhaustive. Chapter 3 includes additional case examples. Finally, a search using Dutch terms was conducted to better understand the context in the Netherlands.

## 2.4. Case study Cartesius

The case study focuses on a neighbourhood analysis of Cartesius, integrating both primary data collection and contextual understanding. A survey was utilised to gather information about the residents' mobility patterns and attitudes. The survey aimed to collect factual information regarding car ownership and usage, as well as revealed travel behaviour, reasons for relocation and socio-demographics, and residents' perception and satisfaction. To complement the survey findings, informal conversations with a subset of residents were held. This qualitative method enriched the data with personal narratives and deeper contextual understanding.

### 2.4.1. Rationale for a case study approach

Case studies, as described by Stake (1995) and Yin (1994), among others, are valuable for exploring complex, real-world situations where context is critical. This approach allows for an in-depth investigation, making it particularly suitable for analysing low-car neighbourhoods. In this study, the focus on residents' experiences and adaptations to mobility strategies requires a method capable of capturing the nuances of individual and collective behaviours within a specific setting. The case study approach facilitates a detailed examination of how specific mobility strategies are implemented and experienced, which is valuable for evaluating their outcomes. Moreover, it supports the integration of diverse data collection methods, including surveys, on-site observations, interaction with residents, and document reviews, to build a comprehensive understanding.

There are limitations to the case study approach. The findings may be highly specific to the selected neighbourhood, potentially limiting their generalisability to other contexts. To address this, the results are linked to existing literature. Another challenge is the substantial time and resources typically required to conduct a thorough case study. While this thesis project aimed to provide a rich and in-depth evaluation of the selected case, the limited time frame means it was not possible to explore every aspect in exhaustive detail or conduct a larger comparative study. Instead, the focus was on capturing key insights from the unique and relevant case of Cartesius while ensuring the analysis is as comprehensive as possible within the constraints of the project.

## 2.5. Survey

The survey was designed to address sub-questions 2 (*who are the residents?*), 4 (*how do residents perceive the neighbourhood?*), and 5 (*how have residents adapted to the neighbourhood?*), as well as directly addressing the main research question. With the goal of understanding residents' mobility behaviour, revealed preferences, and demographic characteristics. As a method, surveys are less time-intensive for participants and provide an efficient way to collect the data necessary to answer these research questions. The quantitative data obtained from the survey also facilitated straightforward analysis and the development of clear conclusions.

Surveys have certain limitations. They restrict participants from fully expressing their thoughts in their own words and can inadvertently guide their responses. This can lead to varying interpretations of questions, reducing the reliability of the answers. Furthermore, surveys do not provide opportunities for participants to elaborate on their responses. To address these challenges, the survey was complemented by conversations with residents. This mixed-method approach ensured a more comprehensive understanding of the data and mitigated the risk of misinterpretation that could arise from relying solely on survey responses. Despite its limitations, a survey is a suitable and effective method for this case study when paired with conversations with residents.

### 2.5.1. Survey design

This section outlines the design of the survey. First, the overall structure is explained, followed by a discussion of the different topics and types of questions included. Additionally, the rationale for their inclusion and the reasoning behind their formulation are provided. The full survey can be found in Appendix B.

The survey was an online structured closed-ended survey. The survey was constructed in Qualtrics, under a license of Delft University of Technology. The survey consisted of 25 closed questions. The survey was designed to be quick to complete to encourage participation, with the survey taking no longer than 10 minutes to complete. This goal was achieved by avoiding open-ended questions, making it easier for respondents to participate. The decision to omit open-ended questions was justified, as additional qualitative insights were gathered through conversations with residents. The survey was available only in Dutch.

The questions asked in the survey can be divided into five different topics as shown in Figure 2.1. Adaption is linked to mobility behaviour and thus part of the Mobility characteristics block. Perception is a distinct category with questions regarding satisfaction of the neighbourhood and its mobility concept. Each category is elaborated on in the next few sections.


**Figure 2.1:** Survey topics

The first type of data collected were different socio demographic characteristics of the participants. This was done for two reasons; first to check the representativeness of the sample. Second, to be able to find out how socio demographic characteristics influence the results. These questions were placed at the end of the survey to build trust with participants before asking personal questions, which might otherwise make them hesitant to complete the survey. As explained by Tourangeau (2000) and Dillman, Smyth, and Christian (2014), placing these questions towards the end, the likelihood of participants filling them out is increased.

| **Social demographic characteristics** | | |
|---|---|---|
| *Type of data* | *Survey question* | *Background* |
| Age, income, gender, education level, household composition | | To check representativeness of the sample. Different socio-demographic characteristics can influence travel behaviour and attitudes. Important to compare with literature (are the case study residents different or the same as in previous studies). And also important to know to what extent behaviour can be explained by socio-demographic factors, and what can be explained by the built-environment. |
| Previous residential area | Did people live in Utrecht already, in another big city, in a rural area | To assess the influence of prior living environments on mobility preferences and behaviour. If travel behaviour has changed a lot since moving, this could be due to big differences in urbanity. Mobility options in rural areas are really different than in the case study area. This information is used to check if changed travel behaviour is only caused by this difference. |

**Table 2.4:** Survey topic 1 - Social demographic characteristics

The second category was questions regarding residents' mobility characteristics. Ownership of a

drivers' license, car ownership and changes in car ownership were asked. Residents were asked about their pre- and post-relocation travel behaviours. Two measurements were used: 1) frequency of use per modality, and 2) use of modality per trip purpose. These questions were asked both prior to and after relocation to Cartesius. Frequency per mode excluded walking and cycling, as the number of trips would likely be too high for people to make an accurate estimation, which could affect data reliability. Residents were first asked about their current travel patterns, as it is easier for people to recall their present behaviour. Asking about previous travel patterns afterward enhances the accuracy of the responses. This approach follows best practices in travel behaviour survey design. The question regarding people's use of shared modality was directly taken from the inwonersenquête Utrecht, allowing for easy comparison.

| **Mobility characteristics** | | |
|---|---|---|
| *Type of data* | *Survey question* | *Background* |
| Driver's license | | Having a driver's license is a precondition for car ownership and use. |
| Car ownership | Number of cars in the household | To compare with the rest of Utrecht, other car-reduced areas, per age category (socio-demographically comparable group) to see if development is actually low-car. |
| Car disposal | Did people get rid of a car after moving to Cartesius (including reasons) | To assess whether and why residents reduced car ownership. To see if people have adapted. |
| Modal split (before and after move) | Frequency of using different transport modes<br>Which modes are used for different trip purposes | To get insight into the residents' travel behaviour. To see if and how people have adapted. |
| Use of shared mobility | Use of shared mobility options in the past year (e.g., e-bikes, car-sharing) | To identify the adoption of shared mobility services. Use of more shared modes can indicate a certain openness towards shared modality, and new concepts. This might show a more multi-modal traveller. |
| Use of free trip minutes | Were people aware of the offer and have they used it | To explore engagement with shared mobility incentives and their effectiveness in encouraging adoption. |

**Table 2.5:** Survey topic 2 - Mobility characteristics

The survey question regarding mode frequencies was used for calculating the modal split before and after relocation to Cartesius. Since the possible answers were categorised into five different options, weights needed to be applied to calculate the modal split. The answer categories and corresponding weights are presented in Table 2.6.

| **Category** | **Range** | **Applied weight** |
|---|---|---|
| 5 or more times a week | 5 + | 5 |
| 3-4 times a week | 3 - 4 | 3,5 |
| 1-2 times a week | 1 - 2 | 1,5 |
| 1-3 times a month | ∼0,25 - 0,75 | 0,5 |
| less than once a month | ∼0 - 0,25 | 0,15 |

**Table 2.6:** Weights used to calculate modal split

The third block of questions aimed to cover people's perception of the neighbourhood and the mobility options. A simple 4-point Likert scale seemed most suitable for assessing respondents' satisfaction with various aspects. With the 4 point scale, respondents were 'forced' to choose between favourable and unfavourable responses, excluding people's tendency to select a neutral response (Preston and Colman 2000). Another question that was directly taken from the inwonersenquête Utrecht is the satisfaction with the neighbourhood.

| **Perception** | | |
|---|---|---|
| *Type of data* | *Survey question* | *Background* |
| Satisfaction with living in Cartesius | | To determine overall satisfaction with living in the neighbourhood |
| Satisfaction with different mobility aspects (like parking, shared vehicles, cycling infrastructure) | | To determine which aspects are functioning well, and what can be done better. What are residents (un)happy about? To uncover sources of frustration or unmet needs in the mobility ecosystem. |
| Satisfaction with total mobility | Does the neighbourhood meet residents' mobility needs | To assess how well the provided mobility options meet the mobility needs of residents. Perceived alignment of the neighbourhood with mobility needs. When people have answered that the neighbourhood does not satisfy their mobility needs, this might be a sign of misalignment between the built environment and preferred mobility style. |
| Info about parking | Perceived sufficiency of information about parking policies before moving | To evaluate the adequacy of pre-move communication about the parking policy. |

**Table 2.7:** Survey topic 3 - Perception

The next category focused on residents' attitudes. One of the questions assessed how important sustainability is to residents, providing insight into how this influences their mobility behaviour. Another question asked residents to rank five transport modes from most to least preferred, helping to determine if they favour sustainable or car-free modes, and to identify how many car-oriented individuals live in Cartesius. Respondents were asked to rank the modes regardless of distance, this is done in the same wording as used by Bohte (2010) in her study into residential self-selection.

| **Attitudes** | | |
|---|---|---|
| *Type of data* | *Survey question* | *Background* |
| Sustainability importance | | To understand how sustainability-oriented residents are and how this influences their mobility behaviour. |
| Mode preference | Ranking 5 different modes from favourite to least favourite (regardless of distance) | To explore whether residents prefer more sustainable or car-free modes of transport, indicating alignment with Cartesius' mobility goals. To find out if and how many car-oriented people are living in Cartesius. |

**Table 2.8:** Survey topic 4 - Attitudes

The questions on preferences and residential relocation aimed to explore the reasons for moving to Cartesius and the factors that played a role in this decision. One question asked residents to rank different living scenarios, with two opposite options and a middle ground. The middle option highlighted the benefits of a car-free public space while not requiring residents to give up their private car. This

option was designed to appeal to skeptics or those not inclined toward a car-free lifestyle. If they still preferred a traditional neighbourhood, it may indicate a strong preference against the low-car concept.

| **Preferences and residential self-selection** | | |
|---|---|---|
| *Type of data* | *Survey question* | *Background* |
| Preference living scenario | Ranking 3 different living scenarios from favourite to least favourite | Asking people to rank three different types of living scenarios could reveal residential dissonance if the preferred scenario is (very) different from their current residence in Cartesius. |
| Preference urbanity | Do people prefer to live in a city or in a suburb | Cartesius is a highly urban environment. People indicating that they would prefer to live in a suburb with more space rather than a highly urban area with many amenities, shows dissonance. |
| Residential choice | What was important when moving to Cartesius (including perceived alignment with the concept of car-free public space) | To assess whether residents actively chose the neighbourhood because of its low-car concept or despite it. |
| Reason for moving | What were the reasons for moving to Cartesius | When people say that the reason for moving was that this was the only available place at the time, that they did not have other options, etc. that would be an indicator for non-self-selected residents. |

**Table 2.9:** Survey topic 5 - Preferences and residential relocation

### 2.5.2. Data selection and gathering

The survey targeted all current Cartesius residents aged 18 and over, approximately 390 individuals in total.

The survey process began with an initial message in the Cartesius app on December 10, 2024. The Cartesius app serves as the official communication channel for residents. To increase the response rate, a reminder was sent out in the form of a flyer with a scannable QR code to access the online survey. The flyers were distributed to residents' mailboxes on December 18, followed by personal reminders given to some residents during a Christmas event on December 20. A final reminder was sent via the Cartesius app on December 21, and the survey closed on December 23.

Residents participating in the survey had the option to reach out to the researcher voluntarily if they wished to discuss their responses further. One participant chose to do so.

It should be noted that the data collection method, relying on voluntary participation, introduces the potential for selective bias. As the survey was distributed online and through mail flyers, self-selection is occurring. People who have strong opinions about cars, whether they oppose them or highly value them, might be more likely to participate in the survey to share their views on the low-car characteristics of the neighbourhood.

### 2.5.3. Data analysis

Before conducting the analysis, the data was prepared by checking for responses with missing or incorrect entries, which were subsequently removed from the sample. The precise criteria for data cleaning are outlined in Chapter 5.

The data analysis primarily involved descriptive statistics, conducted using IBM SPSS Statistics and Excel. Sample representativeness was assessed by comparing the sample data to data from the target population, obtained from the municipality of Utrecht. Additionally, some comparisons were made with data from Utrecht and the Netherlands to provide reference points for certain statistics.

Cross-tabular analysis was used to examine relationships between different survey questions. Chi-square tests were performed to assess the statistical significance of these relationships, with a threshold of $p<0,05$. For cases where expected cell counts were small (with 20% of cells having fewer than 5 cases), and for 2x2 tables of categorical variables with two categories each, Fisher's Exact Test (as provided by SPSS) was used instead of the Chi-square test to determine statistical significance.

The data was also grouped based on residential self-selection to analyse differences in mobility styles, behaviour, adaptation, and perceptions. Chi-square tests were used to test differences between these groups. The criteria for grouping residents are elaborated on in Chapter 5.

### 2.5.4. Ethical considerations

Participation in the survey was entirely voluntary. The survey began with an opening statement explaining the implications of taking part, including the potential risk of identity being revealed due to the combination of socio-demographic characteristics and the small target group size. Participants were informed that they could skip any question they did not wish to answer. For more sensitive questions, such as those about income, a 'prefer not to say' option was provided, although this was somewhat redundant since participants could also choose to skip the question. This resulted in a slight reduction in available data.

The research did not involve any harmful activities or require participants to act outside their normal behaviour, and therefore can be classified as minimal risk. Apart from the data collected through survey responses, no personal data such as IP addresses or contact information was gathered from participants.

## 2.6. Conversations with residents

Informal conversations with residents were conducted during a neighbourhood Christmas gathering, which provided a valuable opportunity to engage with residents in a relaxed setting. This informal environment encouraged residents to speak freely about their experiences and concerns, with topics related to parking and mobility often arising spontaneously without direct prompting. In some instances, the role of a passive observer was adopted, blending in with residents and overhearing discussions, which led to candid and honest accounts being shared. This approach also helped mitigate response bias, as residents were not influenced by a formal interview setting or the perceived need to provide socially desirable responses.

While these conversations were not recorded, detailed notes were taken immediately afterward. All information gathered from these conversations has been anonymised to ensure that individual residents cannot be identified.

Although it may be more difficult to draw concrete conclusions from these qualitative insights, the information provided a better understanding of the neighbourhood and its residents. The results were not quantified; however, key issues and opinions expressed during these conversations were considered when analysing survey data and forming conclusions. Interacting with the residents has proven to be a really valuable addition to the survey.

# 3

# Literature study on the effect of low-car neighbourhoods on residents

## 3.1. Case examples and implementations

The literature search for the core concept *car-free* highlighted some of the most influential works. A key source is Crawford's book Car-Free Cities (Crawford 2000), along with the widely cited work by Steve Melia, Parkhurst, and Barton (2010), whose definitions of low-car and car-free developments have become the most widely adopted. Another significant source is Nieuwenhuijsen et al. (2019), featured in the book Integrating Human Health into Urban and Transport Planning, particularly the chapter titled Implementing Car-Free Cities: Rationale, Requirements, Barriers and Facilitators. These works have played a crucial role in shaping this research.

A targeted literature search was conducted to identify case studies and evaluations of low-car neighbourhood implementations, using the search terms presented in 2.3. Only European examples were considered, as they provide a more relevant comparison to the case study area. While there are notable car-reduced areas in regions such as Asia, differences in physical, topographical, political, and cultural contexts—such as public acceptance of policies—make them less comparable (Gonzalez et al. 2021).

Some of the most well-documented European examples include Florisdorf in Vienna and Vauban in Freiburg, Germany. Vauban, one of the largest and oldest car-reduced projects in Germany with approximately 2,300 households, is recognised for its parking-free concept rather than being entirely car-free. Florisdorf, a neighbourhood in Vienna with 244 rental apartments, is notable for being one of the first low-car developments in a major city. These two examples are frequently cited in research on low-car residential areas, though many other case studies exist. A comprehensive search into case studies and low-car residential implementations resulted in an overview of key studies, as listed in Table 3.1.

| Type of research | Research | Cases included | Reference |
|---|---|---|---|
| Multiple case study | Critical review of successes and failures in low-car areas. Survey residents across five neighbourhoods | Vauban (Germany), Florisdorf (Austria), GWL (Netherlands), Torup (Denmark), Bo90 (Denmark) | (Scheurer 2001) |
| Case study | Survey (N=422) and interviews with residents | Vauban | Nobis (2003) |
| Case–control study | Evaluated sustainable lifestyles in car-free housing projects, comparing residents of Florisdorf (N=42) to control group (N=46) of Vienna residents | Florisdorf | Ornetzeder et al. (2008) |
| Comparative analysis | Comparison of multiple European low-car developments. A complete document with data from all cases and lessons for future implementations | Vauban, GWL, Stellwerk60 (Germany), Greenwich Millennium Village (England), Hammarby Sjöstad (Sweden), Houten (Netherlands), Sihlcity (Switzerland), Västra Hamnen (Sweden) | Foletta and Field (2011) |
| Case study | Focus Group Interviews (10 focus groups of 5-8 participants), comparison to other low-car areas | Brøset (Trondheim, Norway) | Thomsen and Löfström (2011) |
| Multiple case study | Interviews with residents in car-reduced areas | Vauban, GWL, Zermatt (Switszrland) | Höjemo (2015) |
| Case study | Focus on parking policy and residential satisfaction. Survey (N=295) and interviews with residents (N=15) | Porslinsfabriken (Sweden) | Antonson, Hrelja, and P. Henriksson (2017) |
| Case comparison | chapter from the book 'urban sustainable transitions' | Vauban, Florisdorf | Späth and Ornetzeder (2017) |
| Multiple case study | Interviews with residents (N=54) and survey (N=571) across 9 different neighbourhoods | 9 developments incl. Stellwerk60, Saarlandstrasse (Germany) | Baehler (2019) |
| Comparative analysis | Review of 16 low-car areas with low parking norms, based on secondary data | 16 areas incl. Vauban, Florisdorf, Hammarby, Stellwerk60, Viva (Sweden), Porslinsfabriken | Sprei et al. (2020) |
| Multiple case study | Interviews (N=22) on mobility practices from residents' perspectives | K6 (Germany), Lincoln (Germany) | Selzer and Lanzendorf (2022) |
| Case study | Survey (N=339) among residents of car-reduced area. Study looks at effect of residential self-selection on travel behaviour | Lincoln | Klein, Klinger, and Lanzendorf (2024) |

**Table 3.1:** Summary of research on low-car neighbourhoods

The work by Scheurer (2001), despite being over two decades old, provides a comprehensive and thorough critical review of several low-car areas, with findings that remain relevant today. Nobis (2003) was among the first to conduct an extensive case study, including interviews and a survey of 422 residents, making it a pioneering study of low-car developments on such a scale. Additionally, Ornetzeder et al. (2008) offered early insights into the differences between residents of low-car areas and those living in more conventional neighbourhoods through a case-control study. Comparative analyses by Foletta and Field (2011), Baehler (2019), and Sprei et al. (2020) examined multiple low-car residential areas, with Baehler (2019) in particular providing valuable insights from extensive surveys and interviews with

numerous residents.

In reviewing these case studies, the focus was on evaluating how these low-car developments have been assessed and identifying gaps in the existing research. The following sections highlight key findings from the literature, including lessons learned for future low-car developments. These findings are based on the studies listed in Table 3.1, as well as other studies. Including scientific articles as well as documents reporting about low-car neighbourhoods and other grey literature. The next section presents the main findings on the factors that shape residents' perceptions of low-car neighbourhoods.

### Information and communication

The success of low-car neighbourhoods depends on effective information dissemination and expectation management (Nieuwenhuijsen et al. 2019). Toersche (2023) emphasises that *'it is crucial to provide a user-friendly and effective, interactive communication medium, and the language should be simple.'* A prime example of best practices can be seen in Greenwich Millennium Village, where new residents receive comprehensive information on sustainable living, resulting in car use being half that of surrounding areas (Foletta and Field 2011).

Other cases have been less successful. In Stockholm, Hammarby Sjöstad was originally planned as an eco-village with limited parking. However, the apartments were marketed as standard housing, without promoting the environmentally conscious concept behind the development. As a result, many residents moved in expecting to continue using their cars for daily transport. Frustration over the lack of parking led to protests, and over time, the number of parking spaces in the area increased significantly (Thomsen and Löfström 2011). This example highlights the importance of providing clear information in advance. Similarly, in Viva, pre-survey data revealed that 66% of respondents intended to keep their cars despite the absence of residential parking (Sprei et al. 2020). This underscores the need for transparent communication about parking policies, which is not always done effectively. The case of K6 in Darmstadt further illustrates this issue. There, residents parked their cars illegally within the neighbourhood because they were unaware of the designated parking areas at its periphery (Selzer and Lanzendorf 2019). Cities like Oslo and Copenhagen, however, have successfully implemented car-reduction measures. According to Doheim, Farag, and Badawi (2020), transparent communication about the expected benefits played a key role in their success.

### Residents participation

Public participation is another critical factor in the success of car-reduced neighbourhoods. Studies emphasise the need for governments to engage citizens in the planning process of low-car areas through accessible and effective communication (Thomsen and Löfström 2011; Nieuwenhuijsen et al. 2019). Through interviews with residents, Höjemo (2015) found that community involvement played a significant role in the success of car-reduced areas such as Zermatt, Vauban, and GWL-Terrein. Späth and Ornetzeder (2017) explain this by stating that *'involving future residents in the planning process fosters emotional attachment, co-determination, and active community-building.'* Antonson, Hrelja, and P. Henriksson (2017) take this further, arguing that it is essential to find ways to involve residents in planning or to manage their resistance and the impact on their daily lives [when implementing restrictive parking requirements].

### Community feeling

Across many of the case studies, residents have reported feelings of 'being part of a special community'. Studies on Greenwich Millennium Village reveal that residents value the sustainable design and enjoy being part of a unique community (Foletta and Field 2011). Living without a car often presents a mental challenge linked to personal identity (Sheller and Urry 2000; Hiscock et al. 2002). It can be seen as a choice that requires justification, as people are differentiating from the majority (Baehler and Rérat 2022). Being part of a community and being surrounded by like-minded car-free individuals helps in sustaining this lifestyle. Baehler (2022) further emphasises that car-free living necessitates a mobility culture where not owning a car is normalised, supporting the concept and ethos of sustainable living.

### Public space

The quality of public space is a key factor in the success of low-car neighbourhoods. One of the main benefits for residents is the creation of a car-free environment, which enhances the liveability of the

area (Scheurer 2001). Studies highlight that carefully planned public spaces play a crucial role in reducing car dependency and making alternative transport options more attractive in low-car environments (Steve Melia, Parkhurst, and Barton 2010; Nieuwenhuijsen et al. 2019). Research on Florisdorf shows that the absence of cars significantly influenced how public spaces are used, leading to stronger community engagement and more environmentally sustainable living (Ornetzeder et al. 2008). Furthermore, a car-free living environment is generally positively perceived also beyond the pro-car-free communities. Stated preference surveys by Borgers et al. (2008) and Borges and Goldner (2015) found that the majority of Dutch people would like to live in a visually car-free area (as long as personal car use and ownership is not restricted). The benefits like improved safety, more space for greenery and a more child-friendly environment are widely acknowledged (Scheurer 2001; Höjemo 2015).

The findings are summarised in Table 3.2, categorised into four key areas. When implemented effectively, these factors can greatly enhance residents' perception of low-car neighbourhoods. However, if these aspects are poorly executed or of insufficient quality, they may lead to frustration and resistance among residents.

| Category | Key Points | Reference |
|---|---|---|
| Information and communication | Clear communication of the neighbourhoods' mobility concept | Thomsen and Löfström (2011) |
| | New residents receiving information on sustainable living | Foletta and Field (2011) |
| | Managing expectations regarding car use and ownership prior to moving | Sprei et al. (2020) and Selzer and Lanzendorf (2019) |
| | Transparent communication of benefits | Doheim, Farag, and Badawi (2020) |
| Public space | Safe and child-friendly outdoor areas | Scheurer (2001) |
| | Closeness to nature and greenery in public spaces | Höjemo (2015) |
| | Alternative use of space due to absence of cars | Ornetzeder et al. (2008) and Nieuwenhuijsen et al. (2019) |
| Community feeling | Residents feel part of a special community | Foletta and Field (2011), Späth and Ornetzeder (2017), and Baehler and Rérat (2022) |
| | Mobility culture that normalises non-car ownership | Baehler and Rérat (2022) |
| Participation | Public participation in planning low-car areas | Thomsen and Löfström (2011), Nieuwenhuijsen et al. (2019), and Hrelja and Rye (2023) |
| | Early involvement of future residents | Späth and Ornetzeder (2017) and Höjemo (2015) |
| | Managing resistance | Antonson, Hrelja, and P. Henriksson (2017) |

**Table 3.2:** Key factors and lessons from low-car neighbourhood case studies

These first four categories highlight general factors influencing residents' perceptions of low-car neighbourhoods, regardless of the specific measures implemented. However, beyond these overarching aspects, the success and perception of low-car areas are also shaped by concrete policy measures and design strategies. The next section explores the various push and pull policy measures employed in low-car residential developments, detailing how specific interventions further influence residents' mobility choices and satisfaction. This section also includes a summary table of key policy measures similar to the overview presented above.

## 3.2. Low-car policy measures and their effects on residents' perception and adaption

The policy measures discussed in this section are derived from both case examples and general studies on low-car areas. Additionally, a more targeted search into specific measures was conducted, with most sources identified through a snowballing technique. Measures were selected based on their relevance to this study. While broader policies, such as taxes on fuel, vehicles, and congestion, can reduce car use on a larger scale, this thesis focuses on neighbourhood-level measures that directly contribute to low-car developments. National-level measures, like fuel taxes, are out of scope. Within this scope, numerous measures exist, which can be classified into push and pull strategies.

Push factors, as the name suggests, are car-restrictive measures that make car use less convenient, aimed at *pushing* cars out of streets, out of sight, and away from our immediate living spaces. These measures include actions like limiting access and creating disincentives to drive. On the other hand, pull factors work to encourage people to shift away from car use by providing attractive and viable alternatives, actually *pulling* people out of their cars. Successful car-reduced developments integrate both push and pull factors (Müller and Reutter 2022; Kuss and Nicholas 2022). Furthermore, Selzer and Lanzendorf (2019) underscore that this dual approach not only reduces car dependence but also helps in revitalising the social functions of streets.

### 3.2.1. Push factors: car reducing measures

One of the most direct methods to reduce cars is physical access restrictions, such as barriers that lower only for emergency services. Similar restrictions are commonly applied in pedestrianised city centres and neighbourhoods designed to eliminate through-traffic (Hrelja and Rye 2023; Rye and Hrelja 2020). However, research suggests that in the Netherlands, such direct restrictions, such as reducing road capacity or limiting car accessibility, are less common. Instead, parking management is the primary tool used to discourage car use, as broader policies like road pricing remain politically sensitive. Nevertheless, financial and legal measures are part of the possible measures. In Vauban for example, people need to sign a yearly legal form stating whether or not they own a car. People that own a car must purchase a parking space for €18,500 - €22,500 (+ monthly maintenance fee of €70) (Verein für autofreies Wohnen, 2010), creating a significant financial barrier to car ownership. Financial disincentives are a particularly impactful push factor (Thaler 2008; Van Ommeren, Wentink, and Dekkers 2011). Vauban is not the only example of such a binding model for car owners to buy a parking spor. A similar model exists in the Ebbingekwartier, where car owners must pay an annual fee of €1,212 for underground parking — ten times the rate for other residents in Groningen (Dagblad van het Noorden 2024). Utrecht has adopted this approach in Wisselspoor, where residents must subscribe to the neighbourhood's central parking garage for a significantly higher fee than nearby residents with standard parking permits (Gemeente Utrecht n.d.). Unsurprisingly, such measures often generate frustration among residents of low-car areas, as they are perceived as unfair compared to the more affordable parking options available in adjacent neighbourhoods.

Since parking policies not only regulate car use but can also influence car ownership, they play a crucial role in shaping travel behaviour. Beyond financial measures, it is essential to explore how parking availability and regulation contribute to the success of low-car developments.

#### The role of parking

Steve Melia, Parkhurst, and Barton (2010) found that in planning policies, the term car-free often refers primarily to the absence of parking. While this perspective is limiting—since a true shift towards low-car living requires a broader package of measures—it underscores parking's strong influence on car ownership and use. Several studies confirm that parking availability directly impacts both car ownership and car usage (Sprei et al. 2020; Christiansen et al. 2017; Ison and Mulley 2014; McCahill and Garrick 2010; Nash and Whitelegg 2016; Waerden and Timmermans 2016). Furthermore, restricted parking has been identified as a contributing factor in the transition from car ownership to a car-free lifestyle (Johansson, G. Henriksson, and Envall 2019; Smith, Sochor, and Karlsson n.d.). Even small changes, such as the width of a driveway or the presence of a gate, can influence car use (Guo 2013). How-

ever, Sprei et al. (2020) cautions that establishing a direct causal link between parking restrictions and mobility behaviour is challenging due to the risk of self-selection; many low-car developments already attract residents predisposed to sustainable travel. Similarly, the Kennisinstituut voor Mobiliteitsbeleid states that in the Dutch context, little evidence exists for a strong correlation between parking restrictions and car reduction, as most residents can still park directly in front of their homes (Kennisinstituut voor Mobiliteitsbeleid 2022).

Despite its potential, parking policy has traditionally been reactive rather than strategic. Mingardo, Van Wee, and Rye (2015) argue that parking has often been viewed in an operational rather than holistic urban planning context. In the Netherlands, the average distance between a home and a parked car is just 21 meters, with most residents parking within 10 meters (Kennisinstituut voor Mobiliteitsbeleid 2022). This convenience has contributed to a cultural norm where people feel entitled to park directly in front of their homes, leading to strong public resistance when parking spaces are removed.

However, attitudes are beginning to shift. Parking management is increasingly recognised not only as a tool to reduce car ownership and usage but also as a space-saving strategy that creates more liveable environments (Rye and Koglin 2014; Shoup 2018; Selzer 2021). Many municipalities, including Vienna, San Francisco, Eindhoven, Amsterdam, and Utrecht, have piloted projects where street parking spaces are repurposed into play areas, terraces, greenery, or public art. These initiatives have been widely accepted, mainly for two reasons: (1) the benefits are highly visible, often outweighing the perceived inconvenience of fewer parking spaces, and (2) residents are involved in deciding how the reclaimed space is used, increasing public acceptance.

New parking models are also emerging, shifting away from the door-to-door car use mindset towards a multi-modal mobility system (Knapen et al. 2021). Concepts such as remote parking hubs and varied P+R strategies are gaining traction, though their implementation remains financially challenging (CROW 2021). Many Dutch municipalities struggle to make these models economically viable due to the way parking financing is currently structured. Typically, developers are responsible for funding parking spaces within their own projects, but when parking facilities are located outside the immediate development area, financial feasibility becomes complex.

In Utrecht, parking norms are set as both minimums and maximums to prevent excessive car traffic from new developments (Utrecht 2021). Developers are incentivised to reduce parking spaces by offering alternatives such as extra bicycle parking or shared mobility options (Goudappel Coffeng BV 2020). This trend of lowering parking norms—often to 0.3 spaces per dwelling or less—is gaining popularity. Additionally, innovative agreements are being introduced where developers allocate saved parking costs towards sustainable transport improvements. A notable example is Floridsdorf, where funds that would have been spent on parking were redirected to amenities such as a roof garden, sauna, improved energy standards, car-sharing stations, and ample bicycle parking (Späth and Ornetzeder 2017; Nobis 2003). By demonstrating tangible benefits from reduced parking, these approaches can shift public perception from parking loss to urban improvement.

Table 3.3 provides an overview of the measures covered in this section, with a focus on their impact and whether they are likely to be perceived positively or negatively by residents.

| Measure | Effect | Reference |
|---|---|---|
| Limiting parking availability | Can significantly impact behaviour, reducing car use and ownership; perception depends on combination with other measures | Sprei et al. (2020), Christiansen et al. (2017), Ison and Mulley (2014), McCahill and Garrick (2010), Nash and Whitelegg (2016), Waerden and Timmermans (2016), Johansson, G. Henriksson, and Envall (2019), Smith, Sochor, and Karlsson (n.d.), and Guo (2013) |
| Financial incentives to decrease car use | Very impactful, but higher costs reduce satisfaction | Thaler (2008) and Van Ommeren, Wentink, and Dekkers (2011) |
| Physical access restrictions | Direct impact. Accepted and widely implemented in pedestrianised city centres. Effect in residential neighbourhoods unclear | - |
| Redirecting parking revenue to sustainable transport options or other benefits | Positively perceived, eases the pain of lost parking spaces | Späth and Ornetzeder (2017), Nobis (2003), Rye and Koglin (2014), Shoup (2018), Selzer (2021), and Höjemo (2015) Examples: Zermatt, Vauban, Florisdorf |
| Parking price differences (high costs for low-car area residents) | Negatively perceived | Examples: Ebbingekwartier, Vauban, Wisselspoor |
| Repurposing parking space | Positively perceived with public participation | Examples: Vienna, San Francisco, Eindhoven, Amsterdam, Utrecht |
| Legally binding contract regarding car ownership | Highly impactful due to legal enforcement | Example: Vauban |

**Table 3.3:** Push factors and their effects on residents' perception and adaption

### 3.2.2. Pull factors: reducing car dependency

Complementary to push factors, pull factors also play a crucial role in reducing car dependency. These factors are generally perceived more positively and can be divided into two main categories: the availability of alternatives and the spatial design of the area.

The availability of high-quality alternatives is essential for encouraging residents to live with fewer cars. Research highlights that the biggest barrier to giving up car ownership is a lack of confidence in alternative transport options (Jorritsma et al. 2021). Therefore, ensuring that these alternatives are reliable, convenient, and accessible is important for creating successful low-car environments.

Access to public transport is an important determinant for the success of a low-car residential development. Almost all studies that conclude with some sort of lessons for future low-car development or success factors address the importance of public transport connections. Including Nobis (2003), Scheurer and Newman (2009), Foletta and Henderson (2016), Baehler and Rérat (2022), and Nieuwenhuijsen et al. (2019). Aspects that are mentioned as important are; connection to a larger public transport network, frequencies and timetable of the connections, number of options, and the fare or price. Though some studies overestimate the effect of public transport substituting private car use. Evaluations of case studies have found very different numbers on what share of car trips are replaced by public transport. Financial incentives, such as price reductions or subsidies for public transport use can encourage residents to shift away from car use. (Cervero 2002; Gärling and Schuitema 2007). But it the case of already low-car areas, public transport may replace active mobility options rather than car trips.

Car-sharing is another key alternative. A study from the Netherlands by Nijland and Meerkerk (2017) found that car-sharing is effective in reducing both car ownership and car use. Integrating shared-car parking spaces into public areas near homes can further stimulate their use. While commercial car-sharing services are expanding, they are not yet widely integrated into low-car development strategies. Instead, earlier low-car initiatives often implemented community-based car-pooling systems. More recently, newer forms of shared mobility, such as electric (cargo) bikes and other forms of (electrified) micro-mobility, have gained traction, though they are not yet fully incorporated into low-car mobility packages. Community-based car-sharing models, where residents share a small number of vehicles among themselves, have proven particularly successful in locations such as Florisdorf and other small-scale car-free housing clusters. Unlike commercial car-sharing, which is still perceived as expensive and presents various barriers to adoption (Kent and Dowling 2018; Hahn et al. 2020), communal car-sharing arrangements tend to be more accessible and well-received (Becker, Ciari, and Axhausen 2017; Shaheen et al. 2020).

Active mobility usually plays a significant role in the modal split of low-car residents. Studies confirm that high-quality cycling and pedestrian infrastructure is a success factor for low-car developments (Ewing and Cervero 2010; Steve Melia, Parkhurst, and Barton 2010). Active mobility is closely related to the spatial context of an area. Since distance remains the most decisive factor in mode selection, proximity to amenities is crucial. Concepts such as multiple centres, 15-minute cities, mixed-use developments, and reduced urban sprawl all could contribute to the success of low-car areas. Banister (2008) explains that cities need to be designed so that people do not need to use a car, in terms of quality as well as scale. Accessibility is not only about mobility but also about proximity (England and Eriksson 2020; Elldér, Haugen, and Vilhelmson 2022). As Maat (2009) highlights, the less compact the residential environment, the greater the likelihood of car ownership. Beyond spatial planning, the presence of high-quality infrastructure, such as safe and convenient bicycle parking facilities, is also crucial for promoting active mobility (Baehler 2019).

| Category | Key Points | Reference |
|---|---|---|
| Alternative modes | Car-sharing services, car-pool system | Sprei et al. (2020), Baehler and Rérat (2022), Scheurer (2001), Thomsen and Löfström (2011), and Nijland and Meerkerk (2017) |
| | Community-based car-sharing | Baehler (2019), Florisdorf case study |
| | Accessibility by bike | Scheurer (2001) and Thomsen and Löfström (2011) |
| | Access to public transport | Nobis (2003), Scheurer (2001), Foletta and Field (2011), and Nieuwenhuijsen et al. (2019) |
| | Shared (micro) mobility options (e-bikes, cargo bikes) | - |
| | Bicycle parking facilities | Baehler (2019) |
| | Good infrastructure for cycling and walking | Ewing and Cervero (2010) and Steve Melia, Parkhurst, and Barton (2010) |
| | Financial incentives for public transport use | Cervero (2002) and Gärling and Schuitema (2007) |
| Spatial design, location, proximity | Proximity to services, stores, and amenities | Höjemo (2015), Sprei et al. (2020), and Banister (2008) |
| | Proximity to larger public transport station | Nobis (2003), Scheurer (2001), Foletta and Field (2011), and Nieuwenhuijsen et al. (2019) |
| | Directness of routes for pedestrians | England and Eriksson (2020) |
| | Mixed land use | Banister (2008), England and Eriksson (2020), and Elldér, Haugen, and Vilhelmson (2022) |
| | Compact city design to reduce car ownership | Maat (2009) and Banister (2008) |
| | Bicycle parking and walking facilities | Steve Melia, Parkhurst, and Barton (2010), Nieuwenhuijsen et al. (2019), and Scheurer (2001) |

**Table 3.4:** Key factors and lessons from low-car neighbourhood case studies

### Conclusion

The different push- and pull measures, and the combination and mix of these, determine for a large part how low-car neighbourhoods are perceived. These measures shape not only the residents' perception of such neighbourhoods but also the extent to which they need to adapt their mobility habits.

This section addressed the second sub-question: What factors shape residents' perceptions of a low-car neighbourhood? Referring back to the key themes identified in Table 3.4 and 3.2, six main aspects influence how low-car neighbourhoods are experienced: the quality and use of public space, the availability and attractiveness of alternative transport modes, spatial design, the provision of clear information to residents, a sense of community, and public participation. These factors, when implemented effectively, can enhance acceptance and satisfaction among residents.

However, success does not rely on every factor being optimal. The example of Florisdorf in Vienna illustrates this. While many car-free housing areas are centrally located, Florisdorf demonstrates that such a concept can succeed even in an inner suburb with less-than-ideal public transport accessibility. In this case, the success of the neighbourhood was achieved through a combination of other measures: good cycling infrastructure and the establishment of a community car-pool system (Scheurer 2001; Thomsen and Löfström 2011).

Having identified a set of factors influencing residents' perceptions and how they are typically received,

it is also important to examine the studies supporting these findings. The next section reflects on the quality of the research, potential biases, and gaps in the current literature.

### Quality of reviewed studies and knowledge gaps

Many studies on car-free and low-car neighbourhoods present them as role models. Topp and Pharoah (1994) emphasised that the broader benefit of car-free cities lies less in their direct impact on car reduction and more in their ability to educate and inspire a shift in public attitudes toward car-free living. While this perspective may have been particularly relevant in 1994, the portrayal of low-car neighbourhoods as *'platforms for belief change and cultural adaptation'* still persists today. Mössner (2012) suggests that these neighbourhoods are often deliberately framed as best-practice examples. Similarly, Späth and Ornetzeder (2017), Selzer and Lanzendorf (2019), and Borges and Goldner (2015) describe them as *'role model neighbourhoods that are forward-looking, sustainable, and modern'*. However, this framing can lead to an overemphasis on success stories while overlooking the everyday mobility practices and challenges faced by actual residents. Freytag et al. (2013) further argue that the narratives surrounding these developments may, at times, contrast with residents' lived experiences.

A deeper exploration of daily mobility practices in low-car neighbourhoods remains a gap in the literature. Many researchers have emphasised the need for a better understanding of how residents navigate these spaces in practice (Nieuwenhuijsen et al. 2019; Kuss and Nicholas 2022; Dijk, Givoni, and Diederiks 2018). Selzer and Lanzendorf (2022) specifically call for further insights into the differences between the ideal vision of low-car living and the realities of daily life. This is particularly relevant in the current urban context, where densification and housing shortages mean that a broader and more diverse population will increasingly find themselves living in low-car neighbourhoods. As such, it is crucial to move beyond idealised narratives and best-practice examples to gain a more comprehensive understanding of residents' experiences.

Bias also plays a role, as many studies are conducted by researchers who support the low-car concept, which can lead to overly positive interpretations of findings. Sprei et al. (2020) warn that the quality of these evaluations is often questionable, making it difficult to establish causality. While studies frequently report positive effects on mobility patterns, it remains unclear to what extent these changes are directly caused by neighbourhood design itself. Contextual factors play a significant role, making case study findings less robust than they might initially appear. This is illustrated by an example from Nobis (2003), who states that *'about two-thirds [of respondents] stated that situations do arise where they miss having their own car, but, for half of the people, this does not happen very often.'* While this statement is framed positively, suggesting that most residents rarely miss owning a car, it also implies that for one-third of respondents, the absence of a private car is a frequent inconvenience. However, Nobis does not further reflect on this nuance. This example is not meant to highlight shortcomings in the study itself but rather to illustrate how interpretation can influence the perceived outcomes of research.

A crucial factor often overlooked in these evaluations is residential self-selection. Many residents who choose to live in low-car neighbourhoods already have a predisposition toward sustainable mobility, making it difficult to determine whether the neighbourhood itself drives behavioural change or simply attracts people who would have adopted these practices regardless (Sprei et al. 2020). Without accounting for self-selection, the impact of low-car policies may be overstated. These limitations underscore the need for more critical, context-aware research to better understand how low-car neighbourhoods function in everyday life.

Thus, understanding low-car neighbourhoods requires examining them from the residents' perspective. The next section shifts focus to the people living in these areas, and a further exploration of residential self-selection.

## 3.3. Residential self-selection in low-car areas

While, in theory, car-free neighbourhoods can accommodate a wide range of residents, a distinct pattern emerges in the types of people who live there. These areas tend to be inhabited by higher-income, highly educated individuals, often with young families who prioritise sustainability (Scheurer 2001; Baehler 2019). Baehler (2019) found that in most of the car-free developments examined in his study, families with young children made up around half of the households. Additionally, university-educated residents were significantly overrepresented, which was reflected in the higher-than-average income levels (Ornetzeder et al. 2008). Beyond socio-demographic characteristics, residents of car-free neighbourhoods often exhibit strong environmental awareness and a lifestyle oriented toward ecological responsibility (Kushner 2005).

There are many indications of residential self-selection among residents of low-car neighbourhoods in previous studies. The characteristics of these residents often reflect a strong preference for sustainable mobility, and these neighbourhoods primarily attract individuals who are already supportive of car-free or car-light living. As a result, these developments tend to reinforce existing attitudes rather than challenge car dependency on a broader societal level. For example in the Floridsdorf development, where Gutmann and Havel (2000) found that 73% of the households had never owned a car prior to moving in, suggesting that many residents were already inclined toward car-free living. Späth and Ornetzeder (2017) in their book also describe that in many cases, residents did not fundamentally change their mobility behaviour after moving; instead, they benefited from enhanced conditions that supported their previous travel practices. The frequently mentioned importance of sustainability and environmental awareness among residents of low-car areas further demonstrate the presence of self-selection. Baehler and Rérat (2022), Foletta and Henderson (2016), and Späth and Ornetzeder (2017) portray the residents of their case studies as members of environmentally aware communities, where car-free living is seen as the reason for moving to such an area instead of the reverse where living in such an area influences car ownership. Baehler's study comparing Vauban's car-owning and car-free households further supports this, showing that most car-free households (N=327) cited environmental reasons for not owning a car, with only 12% attributing their car-free status to the neighbourhood's parking restrictions.

Despite these observations, there is a lack of studies that quantitatively assess the extent of residential self-selection or incorporate it into their analyses. A notable exception is the recent study by Klein, Klinger, and Lanzendorf (2024), which addresses self-selection in low-car developments. In a case study focusing on the low-car neighbourhood Lincoln, they have researched residential self-selection and the relative importance of travel considerations in the residential choice of a car-reduced neighbourhood. The study found that around 45% of participants have strong car orientation and did not self-select into the neighbourhood, providing empirical evidence of this phenomenon. But, car ownership rates among the studied participants is 75%, where for the total residents of Lincoln this is 39%. The study focuses on the reasons for moving to the neighbourhood, and does not look into how this effects mobility behaviour. Meaning that for their research this discrepancy was not a problem, but it makes it not comparable with Cartesius. And still leaving the gap of including residential self-selection effects in evaluating low-car neighbourhoods.

Including self-selection is studies is becoming increasingly important. Larger low-car developments are now being planned, incorporating a greater mix of housing types, including apartments, social housing, and various price segments. This shift is likely to introduce new dynamics that differ from those observed in earlier studies, such as those by Scheurer (2001) and Ornetzeder et al. (2008). To explore broader attitudes toward low-car living, stated preference studies have been conducted to gauge public perceptions and willingness to adopt car-free lifestyles (Borgers et al. 2008; Nies 2020; Meester 2021). However, stated preference has its limitations. So a significant knowledge gap remains. What happens when individuals who did not actively choose a low-car neighbourhood find themselves living in one? Leaving open questions about the lived experiences and adaptation processes of those without a prior preference for car-free living.

## 3.4. The interplay between attitude, behaviour, and the built environment

To be able to answer this question and to understand how to incorporate residential self-selection effects into the study, this section covers some more theoretical content, drawing on travel behaviour studies that extend beyond low-car developments. The focus is on the dynamic relationship between people, their (travel) attitudes, behaviours, and the built environment.

Figure 3.1 presents a framework illustrating these relationships. Travel related attitudes, such as mode preference, play a key role in shaping travel behaviour, this relation is depicted with the purple arrow. The built environment also has a direct effect on travel behaviour; its mobility options either facilitate, enable, or restrict residents' daily travel choices (green arrow) (Cao, P. L. Mokhtarian, and S. L. Handy 2009; Ewing and Cervero 2010; Naess 2014). Consequently, relocating to a new environment can trigger behavioural shifts. The influence of the built environment on travel behaviour is however partially mediated by residential self-selection (blue arrow). Individuals often choose locations that align with their mobility preferences, making it difficult to isolate the independent effect of the built environment (De Vos, Ettema, and Witlox 2018; Schwanen and P. L. Mokhtarian 2005; S. Handy, Cao, and P. Mokhtarian 2005).

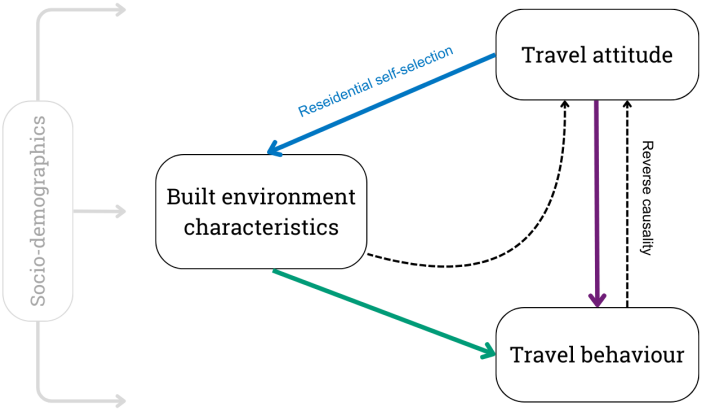


**Figure 3.1:** Travel behaviour, attitude, and the built environment and their relations - adapted from Coevering et al. (2016)

When individuals relocate to areas with distinct mobility characteristics, such as low-car developments, they often adjust their behaviour accordingly (Lin et al. 2017; Næss 2009; F. Wang and D. Wang 2020). This is also what we see in previous case studies on low-car neighbourhoods. For example in Vauban where 80% of residents previously owned a car, but after moving, this has dropped to 15% (Timmermans et al. 2003). One might conclude that the low-car environment had a significant impact on people; leading many to dispose of their cars, which is quite a far reaching decision. However, the presence of residential self-selection complicates the assessment of policy effectiveness. If individuals move to low-car neighbourhoods because they already prefer sustainable mobility, then observed behavioural changes may be self-reinforcing rather than policy-driven. Which was the case in Vauban. Where interviews and surveys with residents revealed that the neighbourhood facilitated the car disposal for people that were already inclined towards living car-free.

To isolate the true effect of the built environment on travel behaviour, it is necessary to account for travel attitude (Bagley and P. L. Mokhtarian 2002; Van Wee 2009). This can be done by looking at residents with attitudes that are not aligned with the built environment. We can see that the purple and the green arrow in Figure 3.1 are both pointing to travel behaviour, but in this case they contradict one another. We can now find out if the built environment arrow can 'override' the attitude arrow. This would provide stronger evidence that neighbourhood design has an independent effect on travel patterns. This is in line with other studies that consistently find that neighbourhood design has an independent influence

on mobility behaviour, even after accounting for self-selection effects (Cao, P. L. Mokhtarian, and S. L. Handy 2009; Naess 2014; Ewing and Cervero 2010). Within the specific context of low-car residential areas this however has not been studied. Low-car neighbourhoods can introduce quite far-reaching measures, making them an extreme case within the broader spectrum of urban design. This creates the potential for strong conflicts between residents' pre-existing attitudes and the imposed mobility concept when people with really opposing attitudes come and live there. If non-self-selected residents also reduce car ownership and usage, this suggests that the built environment can override pre-existing mobility attitudes, reinforcing the effectiveness of low-car developments.

### Reverse causality: the potential for attitude change

Beyond influencing travel behaviour, the built environment may also shape mobility attitudes over time. The reverse causality hypothesis (Coevering et al. 2016; Kroesen 2019) suggests that behaviour change can lead to attitude change. Residents initially resistant to low-car policies may gradually come to appreciate the benefits as they experience alternative mobility options. This feedback loop is illustrated by the dotted black line in Figure 3.1. While travel behaviour can change relatively quickly in response to a new setting, attitudes towards mobility are often more deeply ingrained and may not shift immediately (S. Handy, Cao, and P. Mokhtarian 2005). However, this study captures only a short-term snapshot, measuring behavioural adaptation within approximately two years of relocation. While some residents may have already internalised new mobility habits, others may still be in the process of adjustment. Over time, residents who initially resisted the low-car concept may shift their attitudes, meaning that the full transformative potential of Cartesius is not fully captured within the scope of this study.

### Relocation as a window of opportunity for behavioural change

Relocation itself provides a window of opportunity for shifting travel behaviour. Moving disrupts established habits, creating a unique moment when individuals are more open to reconsidering their mobility choices (Scheiner and Holz-Rau 2013). The mobility biography approach under strikes this by suggesting that major life events, such as changes in residence, employment, or family structure, are often accompanied by shifts in travel patterns (Krizek 2003; Stanbridge, Lyons, and Farthing 2004; Timmermans et al. 2003; Klöckner 2004). Bamberg (2006) found that interventions promoting public transport shortly after a move resulted in long-term increases in transit use, demonstrating how relocation can serve as a catalyst for change.

In the context of this study, Cartesius presents a unique opportunity to observe this process. As a newly developed neighbourhood, all residents are recent movers, meaning that habit discontinuity is already occurring. This aligns with broader findings that newly built low-car neighbourhoods have a greater chance of success than retrofitting existing areas, as relocation itself facilitates behavioural adaptation.

### Linking the study to existing research

This research builds on existing work by integrating the following theoretical perspectives:

- It extends previous findings on the built environment's influence on travel behaviour by specifically examining non-self-selected residents in a low-car neighbourhood.
- It contributes to self-selection research in the context of low-car neighbourhoods, allowing for a more accurate assessment of policy impact.
- It aligns with habit discontinuity research, demonstrating how relocation can provide a critical moment for mobility change.

By incorporating these perspectives, this study aligns with the extensive body of research on the influence of the built environment on travel behaviour and residential self-selection effects. However, it extends these insights to the relatively new context of low-car neighbourhoods, where potential mismatches between travel attitudes and the built environment are more likely to occur.

# 4

# Case study

A case study can provide insight into the lived experiences of residents and allows for a deeper understanding of the case and its context. As highlighted in the research gap, there is a need to examine low-car neighbourhoods from a resident perspective, capturing their experiences and mobility practices. Cartesius offers a real-world example of the emerging high-density, low-car urban neighbourhoods.

## 4.1. Case selection

Cartesius was selected as the case study for this research because it provides a relevant setting to examine mobility measures in a low-car neighbourhood. With 322 households, the neighbourhood offers a sufficiently sized sample for analysis. Although Cartesius is still under development, residents have been living there since April 2023, allowing for an initial assessment of mobility patterns and perception of the mobility concept.

As a high-density urban neighbourhood, space in Cartesius is limited, with an emphasis on green areas and infrastructure for active mobility. The neighbourhood's mobility concept includes very low parking norms and a car-free public space design, aligning with characteristics of low-car developments. Additionally, within the scope of healthy urban living, Cartesius aims to reduce car ownership and use among residents, making it a relevant case for studying the potential impacts of such measures.

Cartesius also appeared to be an interesting case due to issues with parking. Through informal conversations with municipal representatives and a cycling tour of the area, various challenges related to the parking situation were revealed. Residents were sharing tips on where to park for free in nearby neighbourhoods, and the temporary parking facility in Cartesius had been vandalised. Some residents had even taken matters into their own hands by cutting wires to bypass the barrier and avoid paying parking fees. These incidents suggested that at least some residents were dissatisfied with the current policy, highlighting potential areas for improvement. Rather than serving as a best-practice example, Cartesius presented itself as an opportunity to evaluate the complexities of implementing a low-car development in practice.

## 4.2. Introducing the case

Cartesius is a transformative urban development project located on a former Dutch Railways (NS) marshalling yard near Utrecht Zuilen station. The area is being redeveloped into a sustainable, mixed-use neighbourhood with approximately 2,800 homes, a central park, a school, a supermarket, restaurants, and various community facilities.

The development is being realised in phases, with Phase 1 being the only completed and inhabited section so far. This phase consists of two apartment complexes, Solo and Track, which together contain 322 rental homes. Almost all of these are mid-range rental units, with rents capped at €1,037 (as of 2023). The first residents moved into Solo (80 homes) in April 2023, followed by Track (242 homes) in

November 2023.


**(a)** Cartesius on the map - *adapted from Google Earth*


**(b)** Cartesius development phases - *retrieved from Gemeente Utrecht*

As can be seen from Figure 4.1b, Solo and Track (in grey) only form a small part of the entire neighbourhood to be build. Phase 2 to 6 are currently being developed. The entire neighbourhood should be finished by 2032.

Cartesius is going to be a high density low-car urban neighbourhood once it is finished. The vision and impression are very comparable to the many examples of these type of developments we see gaining popularity among many Dutch and European city planners. Fitting within the trend of creating liveable cities. Figure 4.2 gives an impression of what Cartesius is supposed to look like in a few years from now.

**Figure 4.2:** Impression of Cartesius as a high density urban neighbourhood - *retrieved from MRP and Mecanoo*

A defining characteristic of Cartesius is its ambition to become a so-called Blue Zone: a concept inspired by regions worldwide where people live longer and healthier lives.

### 4.2.1. Socio-economic characteristics

Cartesius has a total of 397 residents. The household size in the neighbourhood is notably low, averaging approximately 1.2 persons per household. This is considerably smaller than the average for Utrecht as a whole (1.9), the city's Binnenstad district (1.4), and the national average (2.1) (Utrecht in Cijfers 2024; CBS 2024). The small household size suggests that the neighbourhood mainly consists of single-person households or couples without children. In fact, 77% of households are single-person, while 21% consist of people living together without children. This leaves only 2% for households with children or other less common household compositions, meaning that families with children are nearly absent.

The neighbourhood is characterised by a predominantly young population, with almost all residents

(97%) under the age of 45, and a significant share (63%) being 29 years or younger. Additionally, a large proportion of residents have a higher education background.

The housing in Cartesius consists of apartments in the mid-range rental segment, meaning that rental prices remain below a certain threshold. As a result, there is a diverse range of income levels among residents. The neighbourhood includes many single-income households, particularly young professionals and individuals at the beginning of their careers with relatively lower incomes. At the same time, the high share of highly educated individuals also leads to a presence of higher-income residents.

Overall, the population in Cartesius is relatively homogeneous, characterised by a young, highly educated demographic, with a prevalence of smaller households and very few children.

#### Car ownership

The residents of Cartesius seem to possess many characteristics that typically correlate with reduced car ownership; young people = fewer cars (Kampert et al. 2017), no children = fewer cars (Oakil, Manting, and Nijland 2016; Clark et al. 2014), living in a (dense) city = fewer cars (Maat 2009; Cervero and Day 2008), residence close to a train station = fewer cars (Naess 2014; Cao and Chatman 2016). Only high education is linked to increased car ownership. But, when looking at young high educated individuals, there is a contrary trend visible of reduced car ownership and a preference for more sustainable modes (Kroesen and Wee 2021).

70% of households in Cartesius do not own a car, while 29% have one car, and only 1% own two cars. These figures are lower than the average for Utrecht as a whole, where 64% of the households own at least one car. While younger people generally own fewer cars, car ownership in Cartesius is even lower than among similarly aged groups in the Netherlands and other highly urbanised areas (reference data from Kroesen and Wee (2021) and Kennisinstituut voor Mobiliteitsbeleid (2022)) Even when considering demographic factors, car ownership seems to remain distinctly low.

### 4.2.2. Mobility in Cartesius

Cartesius benefits from a central location with a good connection to the train network with Utrecht CS, the Netherlands' most important train hub, only 10 minutes cycling away. Station Zuilen is right next to the neighbourhood, 5 minutes walking. From there the train takes you to Utrecht CS in 3 minutes. Bus stops are also within walking distance.

Table 4.1 presents some of the relevant numbers about the neighbourhood's mobility aspects. The rest of this section partly answers sub-question 3: 'What mobility strategies and policy measures have been implemented in Cartesius to create the low-car residential area?'

| **Walking** | **Cycling** | **Public transport** |
|---|---|---|
| *Amsterdamsestraatweg* 7 min | *Domplein* 13 min | Utrecht CS 10 min cycling |
| *Hoog Catharijne* 19 min | *Neude* 10 min | Utrecht Zuilen 5 min walking |
| *Julianapark* 10 min | | Train from Zuilen to Utrecht CS 3 min |
| | | Bus stop 5 min walking |
| **Car parking** | **Bicycle** | **Shared modes** |
| Parking norm: 0,18 per residence | Bicycle parking spaces: 780* | Number of shared cars: 4 |
| Parking spaces for residents in garage: 58 | Special bicycle parking spaces: 5* | |
| Price visitor parking: free | | |

**Table 4.1:** Mobility in numbers

The focus of the mobility concept lies on walking and cycling, as these are also aligned with the health aspect of the neighbourhood as a Blue Zone. When the neighbourhood is finished amenities and services should be within walking distance. Since the neighbourhood is not finished this is not the case,

but due to the location of the neighbourhood right in the city many locations can already be reached by either bike or foot.

The parking norm is very low, at only 0,18 parking spaces per residence. There is a parking garage underneath Track for resident parking. Other than these 58 parking spots, residents can not apply for a parking permit. Parking private vehicles in the public space is prohibited, but this is currently not enforced.

In the vision statements it was mentioned that shared cars will play an important role. With numbers for shared cars ranging from 16 or 20 in Phase 1 up to 300 (1 shared car per 10 households) after final completion of the neighbourhood. These numbers are highly ambitious, as normally the calculated rate for new developments is 1:30 (1 shared car per 30 households). Despite the strong words in vision and planning documents, currently only 4 shared cars are placed in the neighbourhood, stationed at the designated shared car parking spots in the public area.

As part of Cartesius' mobility strategy, residents get an introductory subscription for different modalities during the first three years of living in Cartesius. This is done to stimulate residents to use alternative modes. The subscription should include the shared cars, regional public transport, and a MaaS app. As of today, only the shared cars part has been offered to the residents. Residents can sign up to get free trip minutes for the MyWheels cars.

### 4.2.3. Discrepancies between vision and execution of the neighbourhood

Cartesius is still under development, with ongoing construction works and several aspects of the low-car concept not being implemented yet.

As can be seen from the pictures in Figure 4.3, Cartesius' public space is currently far from being car-free. A temporary above-ground parking facility occupies the area where a park is planned for the future. Although the policy prohibits parking in public spaces to promote a car-free environment, the presence of this temporary facility undermines the strategy. The parking fee of about 4 euros per hour is not collected, the policy is not enforced.

**Figure 4.3:** Cars parked at the temporary parking place in Cartesius

In addition to parking issues, discrepancies are observed regarding active modes of transport. While the mobility strategy emphasises walking and cycling, the necessary infrastructure is not yet fully developed. Construction works have resulted in a detour for pedestrians walking to Station Zuilen, and safety concerns have been raised about the main access road (Perronlaan) for both pedestrians and cyclists. Furthermore, the cycling tunnel connecting Cartesius to Wisselspoor, which would provide a shorter and more direct route to the city center and central station, remains closed due to safety concerns,

despite its construction being complete.

As stated in the previous section, availability of shared cars is also below the initially planned level, with only four vehicles currently accessible to residents. Additionally, residents have only received free trip minutes instead of the comprehensive mobility credits package initially promised in planning documents.

The influences of these contextual factors are elaborated on and discussed in Chapter 7.

# 5

# Data analysis and results

This chapter presents the analysis and findings of the study, building on the previous chapter, which introduced Cartesius as the case for this research. The results are structured as follows: first, an overview of the sample is provided through descriptive statistics and an assessment of its representativeness. Next, changes in mobility behaviour before and after relocation are examined, followed by an analysis of how residents perceive the mobility measures in Cartesius. For reference, some of the data was compared to numbers from Utrecht or the Dutch population. Particular attention is given to residential self-selection and dissonance, distinguishing between residents who actively chose a low-car neighbourhood and those who did not. The criteria for defining these groups are explained, and the differences between them are presented. In addition to survey results, Section 5.5 discusses qualitative findings from conversations with residents.

## 5.1. Descriptive statistics

The total number of respondents is 70 (Table 5.1), resulting in a response rate of 22% (calculated by dividing the number of responses by the total number of households). However, this percentage might be an overestimation since multiple people from the same household could have completed the survey. When considering the total number of residents in Cartesius instead of households, the response rate is 18%.

The data was checked for incomplete or illogical responses. Responses that were not marked as 100% complete by Qualtrics were excluded. However, even fully completed surveys could contain skipped questions. Table 5.2 provides an overview of the data filtering steps. Ultimately, all 70 responses were deemed valid and retained for analysis, with no cases requiring removal.

| **Total number of responses** | **70** |
|---|---|
| Initial responses from link in the app | 47 |
| Responses from QR-code | 11 |
| Responses through link after reminder(s) | 12 |

**Table 5.1:** Number of survey responses

| | |
|---|---|
| **Questions skipped or not filled in** | |
| All questions are filled out by every respondent except the ranking questions and the final question about sustainability<br>- Ranking question about living scenario is filled out by 57 people<br>- Ranking question about mode preference is filled out by 63 people<br>- Question about sustainability is filled out by 69 people | |
| **Removing illogical responses** | |
| When answer to both ranking questions is the same as the original order of 1-2-3-4-5 and 1-2-3 | 0 cases |
| People without a driver's license driving a car | 0 cases |
| People without a driver's license in the household owning a car in the household | 0 cases |
| **Minimum time to complete** | |
| The fastest respondent completed the survey in 252 seconds (4 minutes, 12 seconds). This response was checked to see if it made sense, which it did. All questions are filled out and the combination of answers is sensible. | |

**Table 5.2:** Filtering survey responses

### 5.1.1. Sample representativeness

The representativeness of the sample is assessed by comparing the survey data to available demographic data for all Cartesius residents retrieved from the municipality of Utrecht, BRP and RDW. The characteristics used for this comparison are gender, age, household composition, and car ownership. A summary of the comparison is presented in Table 5.3.

| Variable | Sample distribution | | Cartesius distribution |
|---|---|---|---|
| **Gender** | | | |
| Female | 71% | | 54% |
| Male | 27% | | 46% |
| Other | 1% | | - |
| **Age** | | | |
| - | - | 0-14 | <3%* |
| 18-29 | 49% | 15-29 | 63% |
| 30-39 | 49% | 30-44 | 34% |
| 40-49 | - | 45-54 | <3%* |
| 50+ | 3% | 55+ | <3%* |
| **Household composition** | | | |
| single-person household | 53% | | 77% |
| two adults without children | 44% | | 21% |
| two adults with children | 1% | | <3%* |
| single parent household | - | | - |
| other | 1% | | <3%* |

**Table 5.3:** Comparison of survey data and Cartesius data (Municipality of Utrecht, BRP)
**An indication of <3% in the Cartesius data means a count in the data below 10. The exact number is not known.*

One notable finding is the over-representation of women in the sample. The difference of 17 percentage points suggests that the respondents are not fully representative of the total resident population.

In terms of age distribution, the sample aligns somewhat better with the population. Although the categories are not identical, both the sample and the total population consist almost entirely of individuals under 45. The survey participants tend to be slightly older on average. When combining the age distribution with household composition—particularly the absence of children—it can be inferred that the 15-29 category in the population data roughly corresponds to the 18-29 category in the sample, facilitating comparison. However, differences of 14 and 15 percentage points for the 18-29 and 30-44 groups, respectively, indicate some discrepancies in representativeness. Nevertheless, given the research focus, it is clear that Cartesius is primarily inhabited by younger people, which is reflected in the survey responses.

A similar pattern is observed in household composition. The sample is representative when considering only the presence or absence of children—both groups show a very small share of households with children. However, the proportion of single-person households versus couples differs between the sample and the total population.

| Variable | Sample distribution | Cartesius distribution |
|---|---|---|
| **Car ownership** | | |
| no car | 51% | 69% |
| 1 car | 46% | 29% |
| 2 or more cars | 3% | 1% |

**Table 5.4:** Comparison of car ownership from the survey data and Cartesius data (Municipality of Utrecht, RDW)

In Table 5.4, the percentages for car ownership in the sample and the total target group are presented. The sample shows an over-representation of households with cars. This difference could be explained by participation bias. It is likely that residents with strong opinions about mobility were more inclined to fill out the survey, and in most cases, these are the residents who are less satisfied with the mobility concept, primarily car owners.

### 5.1.2. Residents' travel behaviour

Cartesius residents demonstrate a degree of modal flexibility, using an average of 3.8 different transport modes across all trip purposes. For commuting to work or school, residents do not necessarily rely on a single mode but instead use multiple options. Reported car users are for example also using the train and shared cars. For doing groceries or shopping we see that many residents opt for active modes. With 87% saying they use their bicycle for groceries. Which is an indication that amenities are within close proximity, but not in the neighbourhood itself. For leisure activities, either alone or with household members, we see a broad range of different modes being used. This is logical since leisure activities include many different destinations.

Public transport is widely used among residents, while private car use is reported by fewer than half. However, as shown in Figure 5.1, those who do use a car tend to do so frequently—five times a week or more. In contrast, bus, tram, and metro (BTM) services have a higher proportion of infrequent users, with more than half of respondents indicating they use them no more than three times per month. Train use is particularly high, with 49% of residents being weekly train users, compared to only about 10% of the general Dutch population. Overall, 81% of Cartesius residents use public transport at least once a month. Shared micromobility and shared cars are used by fewer residents and less frequently, with the majority of shared car users reporting usage of less than once a month. Figure 5.1 provides an overview of these findings, illustrating the frequency of use for different transport modes, with the dashed parts indicating that people never use a mode.

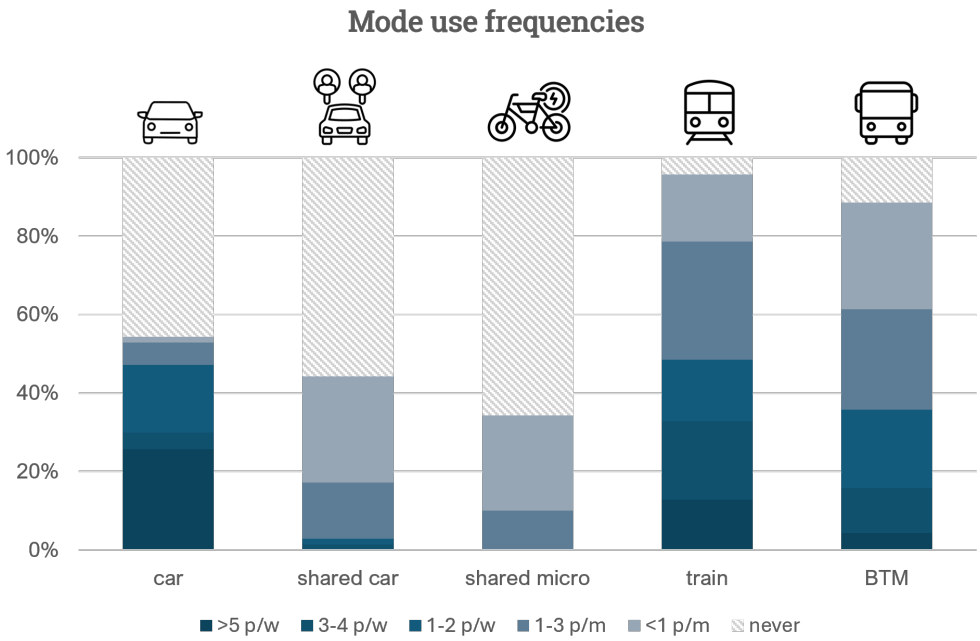


**Figure 5.1:** Use frequency of different modes

Looking specifically at shared car use, it can be seen that this is almost twice as high in Cartesius compared to the rest of Utrecht. So, even though Figure 5.1 shows that shared cars do not account for a large share of the total modal split, their relative use in Cartesius is still notably high. Utrecht, with a similar overall shared mobility offer, provides an acceptable reference point for Cartesius. Furthermore, it can be observed that Cartesius residents have used more shared modes. Figure 5.2 presents the comparison of shared mode use over the past twelve months.

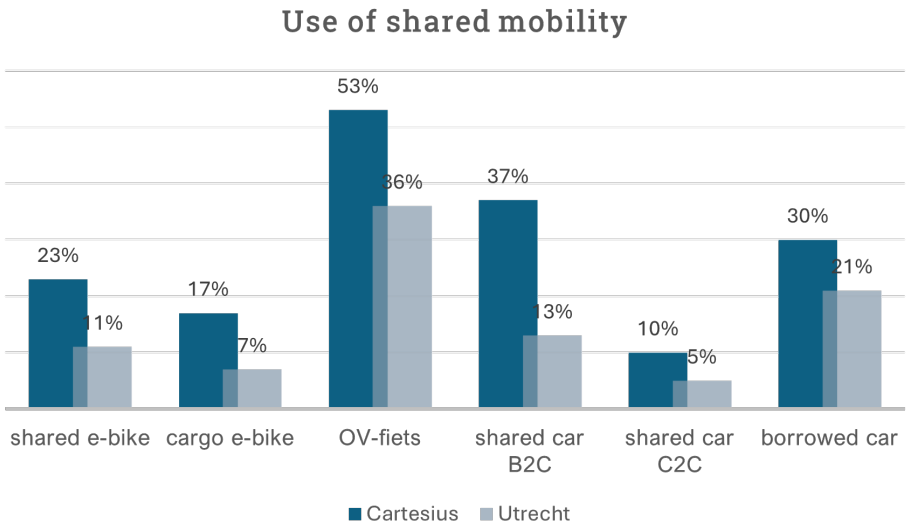


**Figure 5.2:** Use of shared modes in the past 12 months

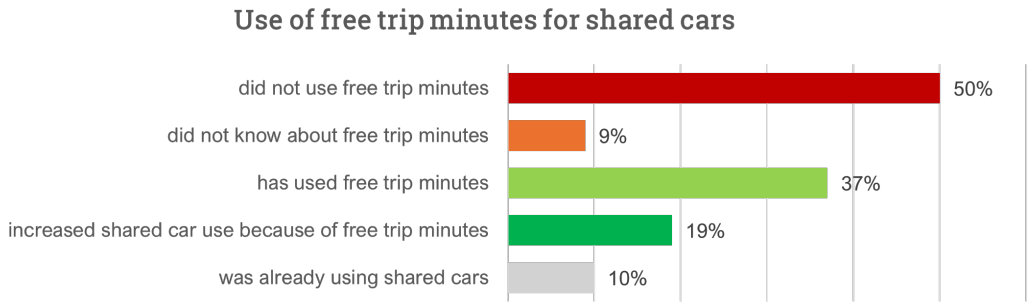


**Figure 5.3:** Use of free trip minutes

37% of the residents in the sample have made use of the free trip minutes for MyWheels provided by the municipality to encourage shared car usage. Four residents used the open answer option to express dissatisfaction with the shared car offer, stating that they find it either too expensive or feel there are not enough vehicles available.

### 5.1.3. Residents' attitudes and preferences about mobility and residential location

The car emerged as a favourite mode for over 25% of respondents. Which is quite a large share of car enthusiasts given the low car-ownership rate and profile of the residents. On the other hand, 20% ranked the car as their least preferred mode, indicating an opposition to car use. Figure 5.4 presents the rankings for all modes asked. Consistent with the high frequency of bicycle trips, the bicycle emerged as the most popular mode.

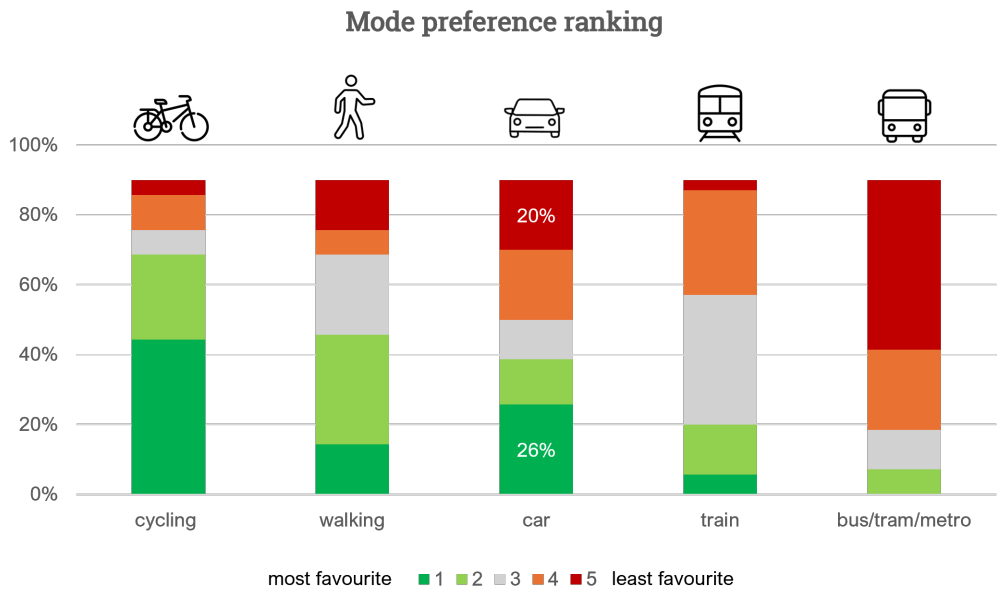


**Figure 5.4:** Mode preference

About one-third of the participants would prefer to live in a suburban area with more space, while the remaining two-thirds favoured a more urban environment with more amenities (Figure 5.5). Revealing some misalignment among the people wanting to live in a suburb - which Cartesius is not.

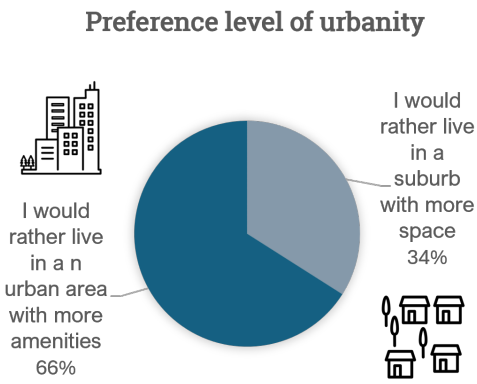


**Figure 5.5:** Preference for level or urbanity

Another question focused on preferences for different types of neighbourhoods, asking respondents to rank three options. It was anticipated that the second option —a low-car neighbourhood with sufficient parking for residents at the periphery (visually car-free concept) — would be the most popular. However, the results were the opposite, as can be seen from Figure 5.6. Less than a quarter of respondents ranked this scenario as their preferred choice. In contrast, 31% selected a traditional neighbourhood with cars in front of their house as their top choice. A slightly larger group, 36%, ranked this option as their least preferred, placing it behind the two low-car scenarios. The low-car, multi-modal neighbourhood was marked as most preferred option by 26% of the respondents, indicating a positive attitude toward car-reduced concepts for at least a quarter of the survey sample. With less people than anticipated going for the middle-ground option, this further reveals the presence of participation bias, where people with strong opinions, either positive or negative, are more inclined to fill out the survey.

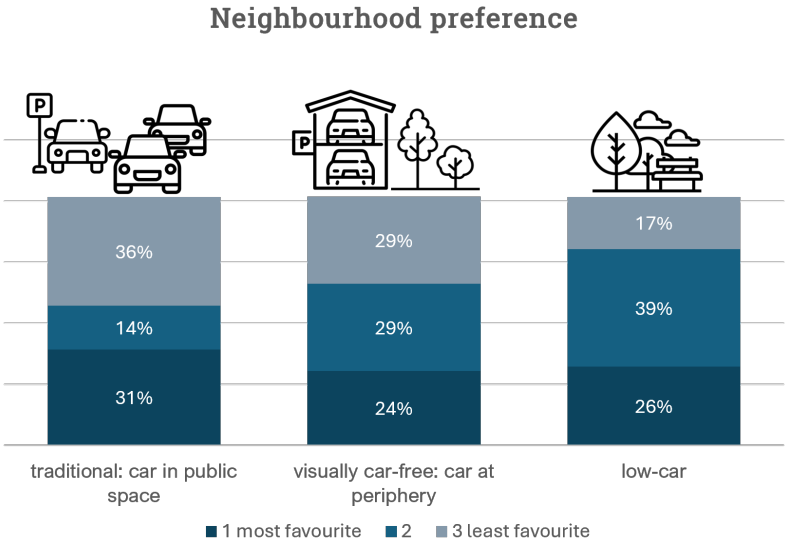


**Figure 5.6:** preference for living scenario

### 5.1.4. Residential relocation

Two thirds of the Cartesius sample are people that had previously been living in Utrecht already. Most people already lived in urban areas, with only 13% being from a smaller municipality, town, or rural area. This suggests that for most of the residents, moving to Cartesius did not come with a drastic change in built environment. As much as 30% had previously lived in city centres; highly urbanised areas. Figure 5.7 gives an overview.

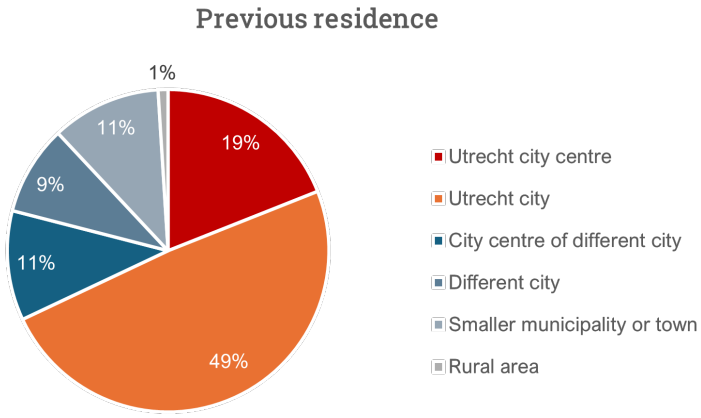


**Figure 5.7:** Overview of where people lived before moving to Cartesius

The most important reasons for moving to Cartesius included aspects of the residence itself and availability of housing. The two most mentioned reasons for move were 'wanting to live bigger' and 'finding a more pleasant residence' (5.8). A substantial amount of people (29%) have chosen the option 'other' and filled in several reasons[1]. Many of them addressing the same topic of housing shortage. One resident had taken the effort to send an email to further explain why they think living in Cartesius had not been a deliberate choice for many of the residents. With many people taking the effort to fill in the blank option to let the researcher know that Cartesius was not exactly a free choice, this reveals the sentiment among the residents that they just 'ended up there', despite the low-car concept.

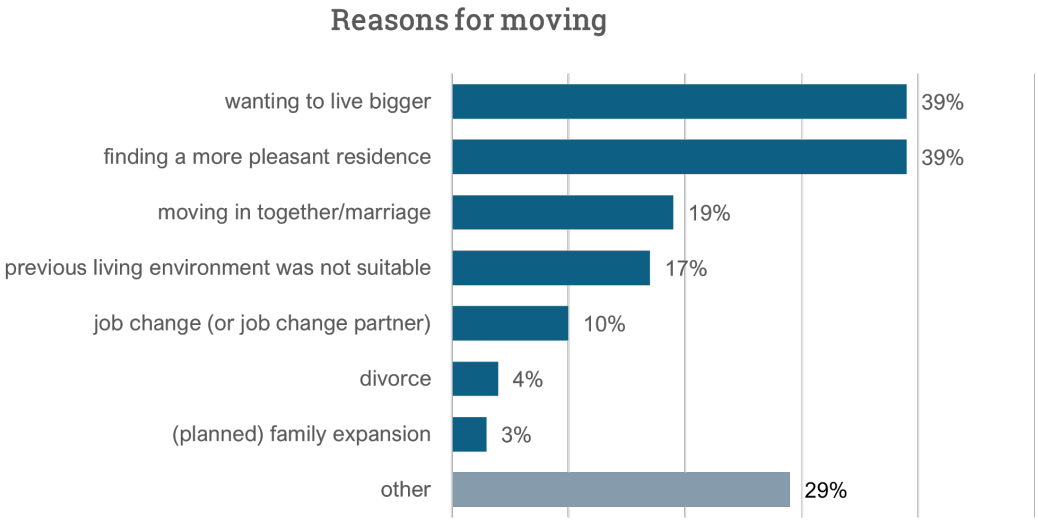


**Figure 5.8:** Reasons for residential relocation

[1] Reasons include: *'Er was een woning beschikbaar' - 'Überhaupt ergens zelfstandig wonen' - 'Woningtekort en mogelijkheden voor plaatsing' - 'Ik had een woning nodig, zat in een tijdelijke woning.' - 'Geen andere optie' - 'het enige appartement dat ik toegewezen kreeg, als je nee zegt ben je zo een jaar verder'*

Figure 5.9 further present the results about which aspects were important when moving to Cartesius. Price was by far the most important to most residents. Followed by proximity to public transport, the energy label of the residence and proximity to work. Interestingly, proximity to public transport was also marked as important by car owners and -users. The availability of shared cars seemed the least decisive factor with more than 80% of the residents stating it was not important or did not play a role. Cartesius' vision on healthy urban living as a Blue Zone was somewhat important to half of the residents. The car-free public space was only noted as important or very important by 16% of the sample.

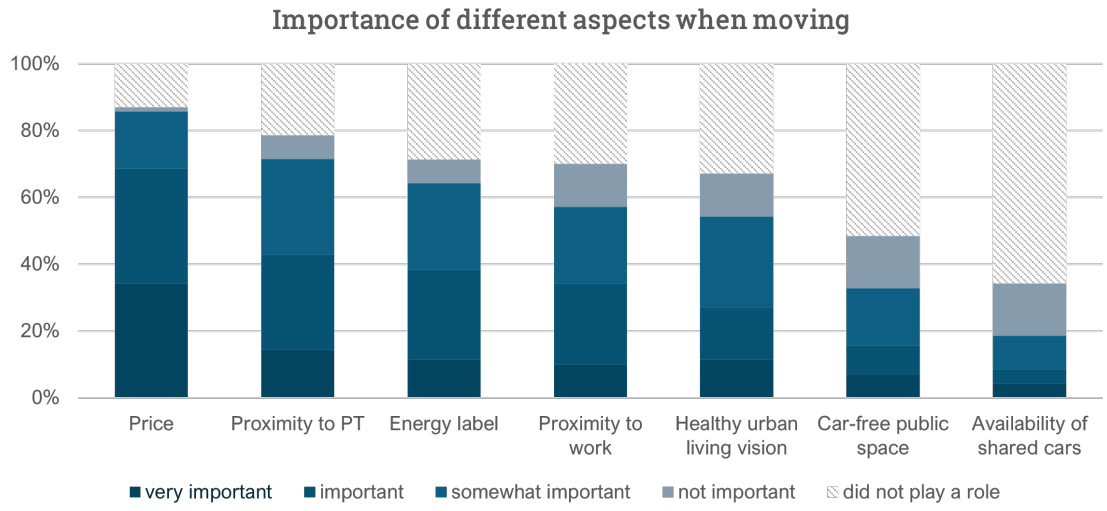


**Figure 5.9:** Overview of how important different aspects were ranked

## 5.2. Changes in mobility behaviour before and after relocation

### 5.2.1. Car ownership change

Car ownership has decreased among the survey group since moving to Cartesius. The number of residents owning a car dropped from 40 to 34; a 15% reduction or an 8 percentage point decrease. A significant share (33%) of current or former car owners have either disposed of a car or are seriously considering doing so (Figure 5.10), indicating that about one-third of car owners have adjusted or are contemplating adapting their travel behaviour. Among those who got rid of a car, two residents disposed of their second car, while six got rid of their only car, so they now live car-free.

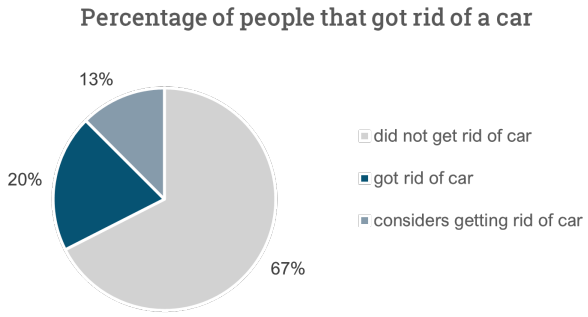


**Figure 5.10:** Car disposal

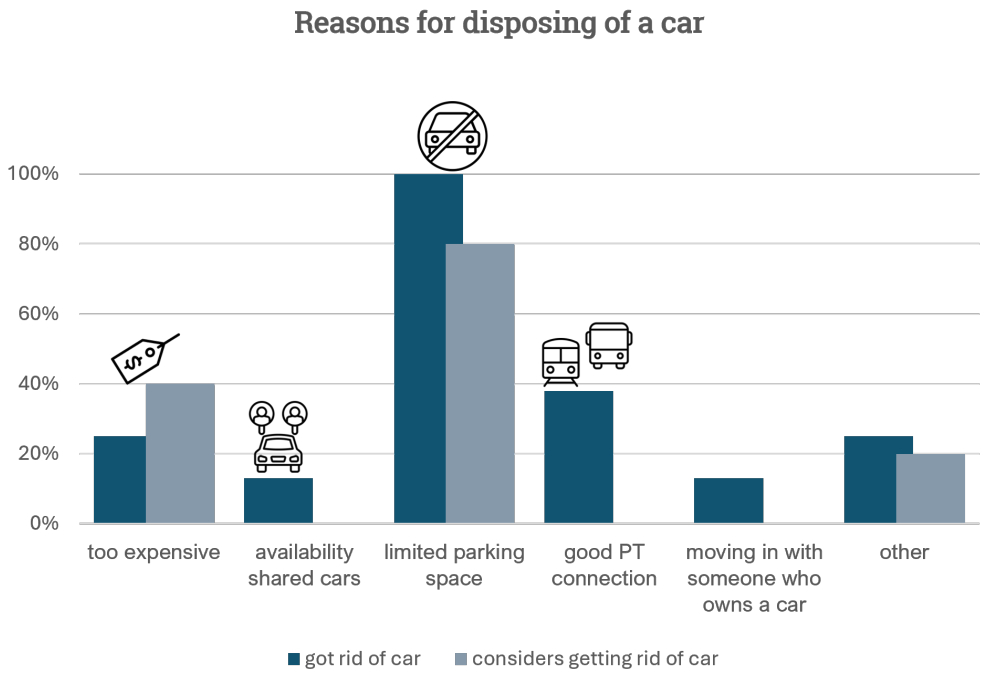


**Figure 5.11:** Reasons for disposing of a car

Everyone that got rid of a car has mentioned not enough parking spaces in the neighbourhood as a reason. The second most popular reason (mentioned by 38%) was good connection to public transport. Figure 5.11 provides an overview of people's answers listing the reason(s) for getting rid of a car, or considering doing so.

It should be noted that the statement 'I am considering to get rid of a car' does not guarantee car disposal, since it cannot be determined how seriously people are considering it, and for which time frame.

### 5.2.2. Travel behaviour change

#### Changes in private car use

Among car owners, 28% report driving less since moving to Cartesius. The number of residents who never drive has increased from 27 to 32; a 19% increase. Overall, car use has declined for 17% of the total sample. Notably, four individuals who previously drove five or more times per week now no longer use a car at all.

Half of those who reduced their car use now make more use of shared cars than before moving. This relationship yields a Pearson Chi-Square score of exactly 0.050, suggesting potential statistical significance. However, the Fisher's Exact Test, which is more reliable for these smaller numbers, does not confirm statistical significance ($p = 0.074$). Similarly, half of those who drive less now use public transport more frequently, though no statistically significant relationship was found (Fisher's Exact Test = 0.163).

Decreased car use is not entirely to be accounted for by individuals moving from rural areas to Cartesius, since people from Utrecht and other high urban areas are also present among the people that drive less.

#### Changes in shared car use

Shared car use has increased for 19 people (27% of total sample). It has decreased for 5. 52 people never used a shared car before moving, since moving to Cartesius this number is reduced to 39; so 13 new users. The free trip minutes are mainly used by residents without a car in the household (relation between car ownership and use of free trip minutes Chi-Square p=0,019). But still, from the car owners,

as much as 23,5% has used the free trip minutes. Half of the respondents reported using shared cars more frequently after trying them with the free minutes, suggesting that this policy was effective in encouraging adoption. However, its effect on car ownership and use remains uncertain. As described in the previous section, no statistically significant relation could be established between reduced private car use and increased shared car usage.

### Changes in public transport use

The total public transport use - meaning either train use, bus/tram/metro use, or both - has increased for 30% of the residents. The number of people using public transport less than once a month or never has stayed the same (13 people). Almost all residents (94%) were already using public transport before moving to Cartesius. We can observe two new train users who previously never travelled by train.

### Changes in modal split

The expected shift in modal split has not been as pronounced as anticipated. While a considerable number of residents report driving less and car ownership has declined, these changes are not immediately reflected in the aggregated modal split data. With many car users using the car 5 times a week or more, this decrease does not have a large impact on the modal split. Figure 5.12 presents the modal split before and after relocation. Public transport has stayed almost the same, with train use being slightly higher post relocation. The use of shared cars has increased the most relatively but because of the low share in general this hardly impacts the overall modal split. The absence of active modes in the modal split pie charts affects how the results should be interpreted. Since these modes are not included, the total 'pie' is incomplete, which makes the relative shares of the measured modes (car, shared car, train, bus/tram/metro, shared micromobility) appear larger than they actually are. If walking and cycling were included, these modes would likely account for a significant portion of the total, reducing the percentages of the other modes. Therefore, when interpreting the results, it is important to consider that the observed shares of car use or public transport usage may seem more prominent than they truly are when viewed in the context of the residents' full mobility behaviour.

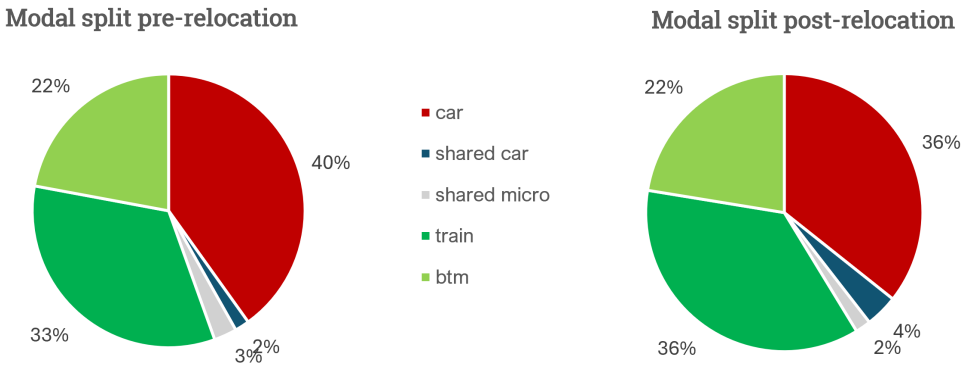


**Figure 5.12:** Modal split change

When looking at the modes used for different trip purposes instead of frequencies, more changes become apparent. Figure 5.13 shows whether modes are used more or less for all the trip purposes combined. For car sharing an increase of 150% was observed. This is left out of the graph due to the scale difference with the other modes.

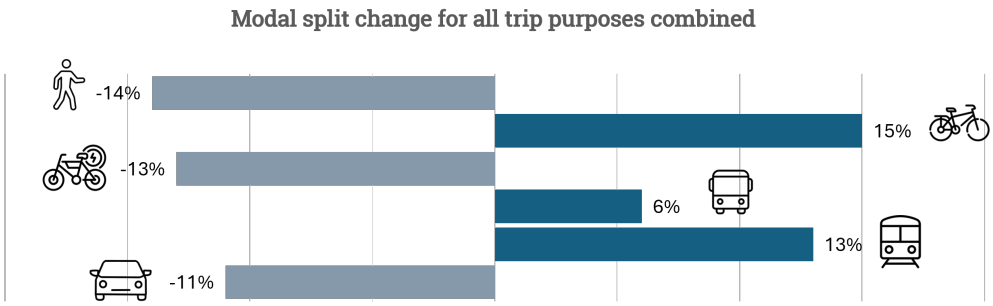


**Figure 5.13:** Change in mode use over all trip purposes

The results provide an overview of the overall adoption of different modes across all trip purposes. The percentages in Figure 5.13 indicate that residents do reconsider and adjust their travel habits to some extent, even though the aggregated modal split seemed to appear largely unchanged.

## 5.3. Perception of mobility measures

### 5.3.1. Satisfaction with neighbourhood and mobility

Overall, 80% of residents report being (very) satisfied with living in Cartesius. While this is a positive result, it is lower than the citywide average of 89%. Since the survey primarily focused on mobility, respondents may have based their overall satisfaction on transportation-related factors rather than a broader assessment of their living environment. This suggests that the lower satisfaction score may not necessarily reflect the overall liveability of Cartesius but rather perceptions shaped by the survey's focus on mobility. When asked specifically about the mobility aspects of the neighbourhood, this further draws a less positive image. More than half of the people feel at least somewhat hindered in their mobility (Figure 5.14).

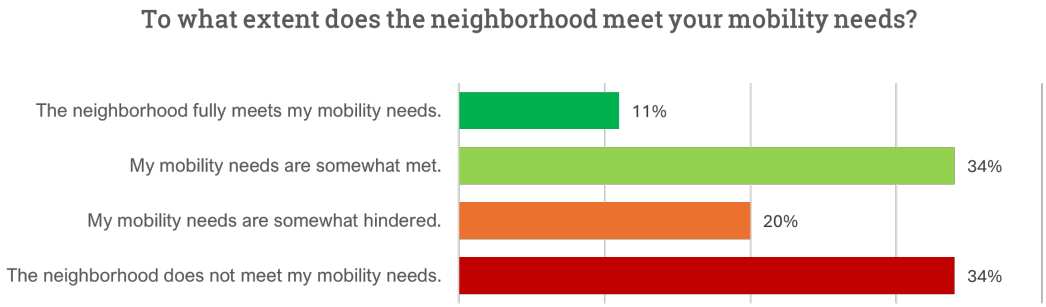


**Figure 5.14:** To what extent the neighbourhood meets residents' mobility needs

To get more insight into as of why people feel unhappy about the neighbourhood's mobility we can look at some different mobility aspects and how satisfied people are with them. Figure 5.15 presents the results. The most prominent red bar, representing dissatisfaction, is the one for parking. That people are unsatisfied about the parking situation in Cartesius was already clear from the on-site observations. Also in conversations with residents, parking was a dominant subject. A notable finding is that people without a car a just as unhappy as those who own one. This widespread dissatisfaction with parking also presents an interesting paradox. The survey did not specify the nature of the dissatisfaction. Do they want more or fewer parking spaces? Do they wish to remove temporary parking to create a fully car-free public space? Or, conversely, do they want more spaces so that every household can obtain a permit? This presents a double-edged sword: people hold opposing views, yet share the same dissatisfaction. This explains why parking dissatisfaction is not solely driven by car owners.

Another aspect scoring quite poorly is accessibility by foot. The detour due to construction works and safety concerns fuelling this discontent. The demand of shared cars is being rated quite positively, despite the complaints about high prices and not enough vehicles. Remarkable is the high number of people not happy with access to the train network. Cartesius has an almost excellent location for train use with Utrecht Central, the Netherlands' primary rail hub, within cycling distance. Varying underlying reasons could be speculated, like people interpreting it as the quality of the first-mile (which is low for walking; the detour, the constructions), or people thinking Cartesius is next to Zuilen, and being unhappy about Zuilen as a smaller station with less destinations and lower frequencies, or people could just be 'spoiled' having lived even closer to a large intercity station previously. Nevertheless this shows that the perception of residents can differ from what policy makers and developers have in mind - and that residents' perception can differ from numbers on paper.

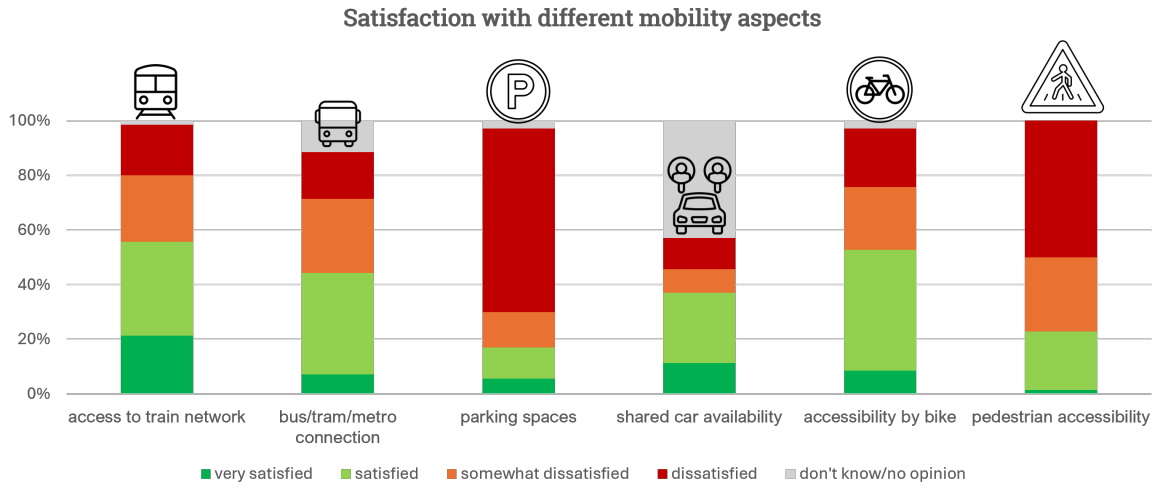


**Figure 5.15:** Satisfaction with different mobility aspects

## 5.3.2. Perception of measures, how well informed do people feel?

30% feels like they were not (enough) or incorrectly informed about Cartesius' parking policy before moving. People that feel well-informed and people that feel poorly-informed own the same amount of cars. There does not really seem to be a difference between how much they drive a car. Frequent car users (5 or more times a week) are however feeling a bit more well-informed. They might have actively sought for information because they rely on their car, or car is important. People without a car or infrequent drivers might not feel the need to check the information as well, because they might have thought it would not apply to them. People who feel they are poorly informed have gotten rid of a car way more often in percentage. Cross-tabular analysis of 'how well informed' and 'car disposal' reveals a statistically significant relationship according to the Chi-Square test; p=0,048.

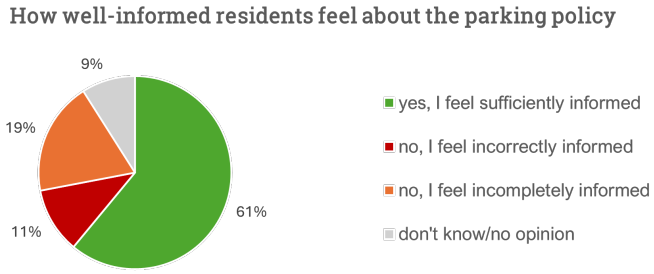


**Figure 5.16:** How well informed about the parking policy did residents feel

The positive measure: the free trip minutes, seems to have been communicated better with only 9% of people not being familiar with it.

## 5.4. Investigating the role of residential self-selection

The following section outlines how residents are categorised into self-selected and non-self-selected groups. Next, the survey responses from both groups are compared, allowing for an analysis of how self-selection influences travel behaviour and perceptions of the low-car concept. The survey results are analysed to identify differences between self-selected and non-self-selected residents in terms of mobility adaptation and satisfaction levels. Cross-tabulation and chi-square tests ($p < 0.05$) are used to identify statistically significant differences between the two resident groups.

### 5.4.1. Dividing residents into self-selected and non-self-selected groups

The approach for grouping residents followed a stepwise process: all residents start in a single group, and those who met any of the defined criteria for non-self-selection or dissonance were reassigned to a separate non-self-selected group. The remaining residents formed the group which represents individuals who could have self-selected into the neighbourhood. The choice to filter out non-self-selected residents rather than identifying only those who clearly self-selected is intentional. This approach ensures that we capture not only those whose behaviour contradicts the mobility concept but also those who may have moved to Cartesius for unrelated reasons and whose travel patterns coincidentally align with the low-car environment. Chapter 7 provides a reflection on this approach and the final group composition. Table 5.5 presents an overview of the indicators and their corresponding criteria, which were directly derived from the questionnaire and used to assign residents to the non-self-selected group.

The strongest indication of non-self-selection comes from residents who explicitly state that they moved to Cartesius out of necessity; because it was the only available option at the time, or because they had limited choices due to housing shortages. Beyond this direct evidence, other indicators of residential dissonance can be used to identify non-self-selected residents. Since self-selection implies a match between personal mobility preferences and the neighbourhood's mobility concept, the presence of dissonance, such as frequent car use or a preference for car-oriented living environments, suggests the absence of self-selection.

| Indicator | Criterion | Reason | N cases |
|---|---|---|---|
| Reason for moving to Cartesius | 'Other' - only available option, no choice, housing shortage, waiting list rental apartment, … | The person did not actively choose this neighbourhood based on its mobility concept but rather moved due to external constraints | 18 |
| Preference living scenario | Traditional, car parked in front of house as #1 | Indicates a preference for a more car-oriented living environment, which is misaligned with the low-car concept of Cartesius | 22 |
| Mode preference | Car as #1 | Suggests a strong preference for car use, which conflicts with the intended mobility concept that prioritises other modes | 18 |
| Modal split - car use | Car use 5 times a week or more | Reflects a high dependency on car travel, contradicting the neighbourhood's aim to promote alternative transport modes | 18 |
| Car ownership | 2 or more cars in household | Suggests a reliance on private vehicles, which is inconsistent with the car-reducing ambitions of the area | 2 |

**Table 5.5:** Criteria used for assigning people to group of non-self-selected people

Some additional indicators were considered for inclusion but were ultimately omitted for various reasons. Below is an explanation of why these indicators were not used:

The first question that initially seemed relevant was about people's preference for living in a city or a suburb. This variable was analysed to see if it aligned with responses about preferred living scenarios. However, the results did not show the expected consistency. It was assumed that people who preferred a suburban environment would be more likely to favour a traditional neighbourhood, while those who preferred a highly urban area would choose the car-free concept. However, the way respondents interpreted 'suburb' versus 'urban' varied significantly. The vision of Cartesius, with ample green spaces and well-designed public areas, may not be perceived as highly urban by some residents. As a result, someone selecting 'suburb with more space' might still feel aligned with Cartesius' concept. The Dutch term *buitenwijk met meer ruimte* (suburb with more space) can have a positive connotation, evoking images of larger homes and green surroundings, whereas *hoog stedelijk* (highly urban) might be associated with grey, asphalt-heavy environments with high-rise buildings. Because these descriptions are brief and open to interpretation, the responses do not reliably indicate residential self-selection. Cross-tabulation analysis confirmed that suburban or urban preferences did not consistently align with preferred living scenarios. Given these inconsistencies, it made more sense to exclude this variable and rely solely on the question about preferred living scenarios.

Another potential indicator was the level of awareness regarding parking policies before moving in. If residents felt uninformed, this could suggest they did not consciously self-select into the neighbourhood, as they were not fully informed in their decision-making process. However, an opposing argument is that even those who received sufficient or accurate information beforehand might still feel deceived by the current situation. With the temporary free parking spaces. Because this question could capture both scenarios (genuine non-self-selection and dissatisfaction due to unexpected deviations from the original plan), it was not a reliable indicator and was ultimately not used.

Lastly, using responses about the factors influencing residential choice was considered. Certain priorities, such as proximity to public transport, availability of shared cars, and the car-free public space, could indicate self-selection. However, identifying self-selection based on just one of these factors was not sufficient. A stronger case could be made by looking at specific combinations of responses, but even then, it would not provide a definitive indicator of non-self-selection. For example, residents who selected 'car-free public space' as an important factor in their decision to move to Cartesius are likely to have self-selected. However, the absence of this response does not necessarily indicate non-self-selection; residents could still have deliberately chosen low-car Cartesius for other reasons, such as its location near a train station or its cycling accessibility. Since car-free public space is only one aspect of the reduced-car mobility concept, this question alone was not a decisive indicator and was therefore not included.

The final outcome using the criteria as mentioned in Table 5.5, results in a group of 40 non-self-selected people, representing 57% of the total sample.

### 5.4.2. Comparison of self-selected and non-self-selected groups

The survey responses of both groups are compared. Table 5.6 presents an overview, highlighting both notable contrasts and variables that show little to no difference. Key findings are discussed below.

| | Self-selected residents (N=30) | Non-self-selected residents (N=40) | Significance |
|---|---|---|---|
| **Mobility behaviour adaption after relocation** | | | |
| Percentage of car owners that have gotten rid of car or are considering it | 50% | 28% | ns |
| Percentage of people using more PT since moving | 23% | 35% | ns |
| Percentage of people using shared cars more often | 40% | 18% | p = 0,036 |
| Percentage of people who have reduced car use | 45% | 22% | ns |
| **Perception of neighbourhood's low-car concept and sustainable mobility measures** | | | |
| Percentage of people that are (really) content with living in Cartesius | 83% | 78% | ns |
| Percentage of people that say the neighbourhood meets their mobility needs | 53% | 40% | ns |
| Satisfaction with parking spaces, accessibility by foot, accessibility cycling, availability of shared cars, access to train network | No difference | | |
| Satisfaction with connection to bus/-tram/metro | More satisfied | More dissatisfied | p = 0,022 |
| Percentage of people that feel well-informed about parking policy | 70% | 55% | p = 0,035 |
| **Socio-demographic characteristics** | | | |
| Percentage of car-free households | 80% car-free | 30% car-free | p < 0,001 |
| Socio-demographics (education level, age, gender, household composition) | No difference | | |
| Previous residential area | No difference | | |
| **Attitude and preferences** | | | |
| Mode preference | Self-selects like bicycle as a mode more | | p = 0,017 |
| | Self-selects like walking more | | p = 0,002 |
| Attitude towards sustainability | No difference | | |
| Percentage of people that found the car-free public space an important factor for moving to Cartesius | 27% | 8% | ns |
| Importance of price, energy label, proximity to work, Blue zone concept, availability of shared cars | No difference | | |
| Importance of proximity to public transport | Relatively important to both groups | | |

**Table 5.6:** Group comparison of self-selected and non-self-selected residents

By definition, car ownership is significantly lower among self-selected residents, with a much higher share of car-free households in this group. There is no significant difference, however, in the percentage of people who have gotten rid of a car or are considering doing so. While the percentages differ, the 50% among the self-selected group represents only four residents. The 28% of non-self-selected residents considering car disposal is still notable, indicating that this group also shows signs of adapting their mobility behaviour.

When looking at changes in public transport use, the self-selected group shows little increase. This can be explained by the fact that almost all of these residents were already frequent public transport users, leaving limited room for further growth. In contrast, the non-self-selected group demonstrates clear behavioural change, with more than one-third of these residents reporting increased public transport use since moving to Cartesius.

Overall, the results indicate that residents from both groups adapt their behaviour in line with the goals of reducing car dependency. In both groups, there are signs of lower car use, lower car ownership, and increased use of alternative modes of transport. The use of shared cars has increased across the board, but self-selected residents have adopted this mode significantly more often than non-self-selected residents. This aligns with expectations, as shared cars typically replace private car ownership, and a majority (70%) of non-self-selected residents still own a car, limiting their incentive to switch

The self-selected group shows a stronger preference for active modes such as cycling and walking, which is in line with previous studies. Typically, low-car residents also place a higher value on sustainability. However, the data does not provide statistically significant evidence to support this. This could be due to the way the question was framed; it was a single, brief question. When asked directly, it is no surprise that almost everyone responded that they value sustainability at least to some extent.

When looking at factors influencing the residential move, no significant differences are found between the groups. Even the importance attributed to the car-free public space does not differ significantly - which raises questions about how accurately the groups were defined. However, it is worth noting that only 16% of respondents mentioned car-free public space as an important factor, meaning the low response rate reduces the likelihood of detecting a significant difference. Proximity to public transport emerges as an important factor for both groups. Notably, car owners also indicate that access to public transport influenced their decision, reinforcing the idea that Cartesius residents are flexible in their mobility choices and not dependent on a single mode of transport

A particularly interesting finding is that both groups report similar levels of dissatisfaction with the neighbourhood and its mobility provisions. Self-selected and non-self-selected residents are equally satisfied with living in Cartesius and equally (dis)satisfied with how well the neighbourhood meets their mobility needs. Satisfaction with various mobility aspects ranging from car parking to walkability also shows no significant differences between the groups. Dissatisfaction is widespread and cannot be solely attributed to non-self-selected residents, as was initially expected. It was anticipated that those who did not choose the neighbourhood for its low-car concept and those experiencing residential dissonance would be less satisfied, but the results do not support this assumption.

One notable difference between the groups is how well-informed they felt about the parking policy before moving in. While a majority of self-selected residents reported feeling adequately informed, just over half of non-self-selected residents felt the same, leaving a significant portion who felt incorrectly or insufficiently informed. Given the far-reaching nature of the parking policy, it is notable that a considerable share of residents felt insufficiently informed before moving in.

Regarding socio-demographic characteristics, the sample appears quite homogeneous, with no clear distinctions between the groups based on age, gender, household composition, or education level. Similarly, the previous residential area shows no differences between the groups; both include residents from Utrecht, city centres, and smaller municipalities. This suggests that mobility adaptation in the neighbourhood was not directly linked to where people had lived before.

## 5.5. Qualitative findings

This section presents a description and summary of findings from the conversations with residents and on-site observations. At the Christmas drinks event, a total of about 35 residents were present. The number of people included in conversations either with the researcher, or overheard in group discussions is estimated to be 20.

The residents present at the event acknowledged that they were informed about the low-car concept of the neighbourhood before moving in. They were explicitly warned, one residents described it as: “Weet waar je aan begint, je kunt nu nog terug” (Know what you’re getting into; you can still back out). They

were also told in advance that they would be living in an active construction site and were prepared for ongoing development around them. The overall reaction I get when asking people about this, is that most accept this reality, understanding that they were moving into a developing area. A point of disappointment that is brought up by many residents is the fact that the park is not realised yet. One resident shared: “We kunnen niet wachten tot die parkeerplaats eindelijk vervangen wordt door groen” (We can’t wait for that parking lot to finally be replaced with green space).

Many of the residents present at the event do not own a car, and those who do rarely use it for daily commuting. Instead, they park in nearby neighbourhoods where free street parking is available. One resident noted: “Ik parkeer mijn auto in een andere wijk en loop een kwartiertje naar huis. Dit duurt net zo lang als in de file staan op de Cartesiusweg” (I park my car in another neighbourhood and walk 15 minutes home. It takes just as long as sitting in traffic on Cartesiusweg).

A major frustration is that the local parking policy is not being enforced. While parking was intended to be restricted, free parking remains, leading to overcrowding. One resident leaves work earlier to secure a parking spot: “Ik ga eerder van mijn werk weg zodat ik voor 18u thuis ben en er nog plek is” (I leave work earlier so I can be home before 6 PM and still find a spot). This issue doesn’t only affect car owners, residents who moved in expecting a car-free environment also feel let down: “We dachten in een mooie autovrije wijk te wonen, maar nog steeds staan hier overal auto’s” (We thought we’d live in a nice car-free neighbourhood, but there are still cars everywhere). Most residents are disappointed that the municipality and developers have not stuck to their initial vision: “Waarom is er niet gewoon netjes betaald parkeren?” (Why isn’t there just paid parking as planned?). Others, however, take advantage of the situation, appreciating the free parking for themselves and their visitors: “Scheelt toch weer geld” (That saves some money). Meanwhile, underground parking garages remain largely empty, and the allocation process for parking spaces has been unclear. One resident described the process as unfair: “Ons werd verteld dat er een wachtlijst was, maar uiteindelijk kon de eerste de beste die vrijkomende plekken gewoon claimen” (We were told there was a waiting list, but in the end, anyone could just claim an available spot).

Shared mobility services, such as MyWheels, receive mixed reviews. Some residents appreciate the free ride credits, using them for occasional trips, with one mentioning: “Ik heb mijn rijminuten opgespaard en kan nu met kerst gratis naar mijn ouders” (I saved my driving minutes and can now visit my parents for free at Christmas). However, many find shared cars too expensive. There is skepticism about whether they are more cost-effective than car ownership, especially for infrequent users. Residents remain unconvinced that shared cars can be cheaper than car ownership: “Een deelauto is zo duur, ik geloof niet dat het goedkoper is dan een eigen auto hebben” (A shared car is so expensive—I don’t believe it’s actually cheaper than owning one).

Beyond mobility, residents voiced concerns about the long temporary situation. Many feel they will be living in a construction site for five years, and might never get to experience the green space. Still, most residents remain pragmatic. One noted: “Ja, die visie is inderdaad geschetst, maar we namen het sowieso al realistischer dan hoe het op papier werd voorgesteld” (Yes, that vision was presented to us, but we already took it with a grain of salt). Many admit they would have accepted any available home in Utrecht, regardless of the low-car concept: “Het is niet ideaal, maar we hebben tenminste een woning” (It’s not ideal, but at least we have a home).

Despite frustrations, there is little social unrest. Community-building efforts seem successful, and residents appreciate the opportunity to live in a new, affordable home in a desirable location. Given the housing crisis, some residents feel they have little choice but to make the best of the situation: “Je kunt het je niet permitteren om kritisch te zijn, laat staan een woning af te wijzen” (You can’t afford to be too picky, let alone reject a home).

## 5.6. Conclusion of results

The conclusion of the results chapter is structured around some of the sub-research questions to summarise the main findings.

The second sub-research question explores who the residents of low-car neighbourhoods are in terms of socio-demographics, attitudes, and travel behaviour, and how they compare to residents of other neighbourhoods. The residents of Cartesius can be categorised as multi-modal travellers with an openness towards shared modalities. With many frequent public transport users, and active modes being mentioned the most across different trip purposes. They also seem to have a positive attitude towards walking and cycling, rating them as the most popular modes. The residents have different previous residential areas, but a large share of more than two-thirds was previously living in Utrecht already. For some residents their attitude, preferences and behaviour are not aligned with Cartesius' mobility concept. So despite the homogeneous group in terms of socio-demographics, we can see a quite diverse range of preferences. Cartesius hosts a substantial number of individuals who exhibit signs of non-self-selection, including car-lovers, frequent car users, and those who would have preferred living in a traditional, car-oriented neighbourhood. This indicates that the resident population is more heterogeneous in terms of attitudes and preferences than might have been expected.

The fourth sub-research question examines how residents perceive mobility options and the implemented low-car strategy. The findings reveal a generally negative perception of the neighbourhood's mobility options. More than half of the residents indicate that their mobility needs are not sufficiently met. Accessibility by walking and car parking receive the most negative ratings. From the conversations with residents it becomes even more clear that people are unhappy about the parking situation. It is a well bespoken topic and people, either car owners or not, have something to complain about. Residents also feel like they were not informed enough or incorrectly before moving. Communication via the municipality or developers is perceived as poorly. Positive experiences are mentioned in relation to the free trip minutes provided for shared car use, as some residents report that this incentive encouraged them to use shared cars more frequently. However, concerns about the high costs of shared cars and the insufficient availability of these vehicles persist across some of the residents. Interestingly, there seems to be no significant difference in satisfaction between car owners and non-car owners, or between self-selected and non-self-selected residents, suggesting that dissatisfaction with certain mobility aspects is shared broadly.

The fifth sub-research question investigates whether residents' mobility behaviour has changed since moving to Cartesius. The results show that for some residents, travel behaviour has indeed shifted toward more sustainable modes. Across both groups, self-selected and non-self-selected, car use and car ownership have decreased, while public transport use and the adoption of shared cars have increased. Active modes have become more dominant across various trip purposes, replacing car and public transport trips. However, it is important to note that for the majority of residents, no significant changes in travel behaviour have been observed. This stability can be partly explained by the already low levels of car ownership and use prior to relocation, indicating that the observed behavioural changes are most pronounced among those who previously used cars more frequently.

Overall, these insights provide a nuanced understanding of how residents in low-car neighbourhoods perceive and respond to mobility policies, which will be further explored in the discussion and conclusion chapters. The results show that resident perceptions do not always align with expectations. While mobility behaviour has shifted in the intended direction, dissatisfaction remains widespread.

# 6

# Conclusion and recommendations

## 6.1. Conclusion

This thesis contributes to the existing research on low-car neighbourhoods by addressing the role of residential self-selection. As far as the author is aware, this is the first study that attempts to quantify the presence of self-selection in these neighbourhoods. In doing so, it also provides an initial exploration of what happens when people who did not actively choose to live in a low-car environment move to such an area. While previous research has primarily relied on stated preference methods to predict potential behaviours in these scenarios, this study takes a revealed preference approach by examining the experiences of actual residents, offering a first look at this dynamic in practice.

This study demonstrates that low-car neighbourhoods can facilitate sustainable mobility behaviours even among residents who did not initially choose this mobility concept. Despite not actively selecting a car-free environment, many non-self-selected residents adapted their behaviour in line with the neighbourhood's mobility measures; reducing car ownership and usage while increasing public transport and shared car use. This finding reinforces the idea that well-designed low-car policies can influence behaviour beyond self-selection effects, reinforcing their role as a strategy for managing space scarcity in dense cities while supporting more sustainable mobility patterns.

A significant portion of residents in Cartesius fell into the non-self-selected category (57%). Many respondents explicitly stated they had no other housing options due to the housing shortage. Others were identified as non-self-selected based on residential dissonance, as their survey responses regarding mode preference, ideal living scenarios, and car use frequency revealed that their mobility patterns did not align with the neighbourhood's low-car concept. The high proportion of non-self-selected residents in Cartesius challenges the assumption that people who end up in low-car neighbourhoods do so purely by choice. The findings indicate a broader trend in which more non-self-selected residents are likely to move into low-car neighbourhoods in the future. As cities continue to implement large-scale low-car policies, understanding the impact on a broader range of residents will be crucial for ensuring the viability of these developments.

The study also provides evidence of the effectiveness of certain measures. The parking strategy appears to be effective in reducing car ownership, as 20% of former car owners disposed of their vehicles. Every one of them cited limited parking space as a key reason. Additionally, 13% of respondents are considering giving up their car. Incentives for sustainable mobility can also support behavioural change. More than one-third of residents used the free shared-car minutes offered in Cartesius, and many indicated that this encouraged them to use shared cars more frequently.

When examining mobility behaviour changes since moving to Cartesius, the findings further support the effectiveness of low-car neighbourhoods in reducing car dependency. Car use declined, with 28% of surveyed residents driving less frequently, and public transport use increased for 30% of residents.

Importantly, these behavioural shifts were not significantly different between the self-selected and non-self-selected groups. The use of shared cars increased across the board, though self-selected residents adopted this mode significantly more often, likely because they were less likely to own a private vehicle. The results indicate that residents from both groups adapted their behaviour in line with the goal of reducing car dependency. The presence of non-self-selected residents who also reduced car use or adopted shared mobility modes proves that external factors, such as neighbourhood design and policy, can encourage behavioural shifts regardless of initial preferences.

At the same time, this research highlights challenges that must be addressed. Overall satisfaction with mobility in Cartesius was low, with more than half of residents indicating that the neighbourhood does not meet their mobility needs. No significant differences were observed between self-selected and non-self-selected residents in terms of satisfaction with various mobility aspects of the neighbourhood. Dissatisfaction with parking was equally high among car owners and non-car owners, regardless of self-selection status, though the underlying reasons varied. Similarly, overall satisfaction with living in Cartesius did not differ significantly between the two groups. While it may seem concerning that satisfaction levels were relatively low, the fact that dissatisfaction was widespread rather than concentrated among non-self-selected residents suggests that it is not merely a result of dissonance with the low-car concept. Instead, dissatisfaction is largely due to temporary infrastructure issues and a lack of clear communication about mobility policies—factors that could be improved with better implementation strategies. For instance, 30% of residents reported feeling inadequately or incorrectly informed about the parking policy before moving in. Additionally, pedestrian and cycling infrastructure has not yet been fully developed, which has understandably led to frustration. The absence of green public space, which will eventually be a key feature of the neighbourhood, is another source of dissatisfaction. The fact that no significant differences were found between the two groups in terms of their perception of the mobility measures and satisfaction with them supports that while self-selection does play a role in shaping initial preferences and baseline mobility patterns, its effect on perception of the low-car concept is minimal.

The findings of this study have important implications for the future development of low-car residential areas. First, the results confirm that low-car neighbourhoods can be effective in reducing car dependency, as demonstrated by the observed decline in car ownership and usage. Second, the study shows that the concept can trigger change in mobility behaviour for both self-selected and non-self-selected residents, meaning that large-scale low-car policies could be viable for a broader population beyond those who actively choose this lifestyle. This challenges the assumption that low-car neighbourhoods only succeed when residents are already inclined toward sustainable mobility.

Furthermore, in the case of Cartesius, the negative perceptions reported by residents can largely be attributed to contextual factors and implementation challenges rather than the low-car concept itself. Issues such as incomplete infrastructure, temporary parking arrangements, and inadequate communication about mobility policies contributed to dissatisfaction. These findings confirm that the success of low-car developments depends not only on their design but also on careful implementation and management.

Overall, this is promising news for the future of large-scale low-car developments. Despite possible dissatisfaction from the residents, low-car neighbourhoods can be effective in altering individual travel behaviour in a desired way, which is the central planning goal. If well-executed, these neighbourhoods have the potential to support sustainable mobility even among those who did not initially choose a car-free lifestyle.

## 6.2. Policy recommendations for low-car development

Based on the findings of this study, several policy recommendations are provided to enhance the implementation and effectiveness of low-car policies.

### Enhancing communication with residents

Effective communication is critical in low-car neighbourhoods to ensure residents understand and accept mobility policies. Findings from Cartesius demonstrate how unclear communication can lead to frustration, particularly regarding parking regulations. Many residents were unaware of the exact parking restrictions before moving in, with survey respondents reporting they felt incorrectly or insufficiently

informed about the policy. People need to be explicitly informed about the absence of parking spaces and the inability to obtain permits later. Currently, this information is sometimes hidden in small print or only accessible after multiple clicks, leading to misunderstandings. Additionally, the garage underneath the Track building remains half-empty most of the time, raising questions among residents. There is confusion about who qualifies for a permit and how the allocation process works.

For future low-car developments, municipalities and developers must ensure that residents receive clear, transparent, and early communication about mobility policies. Providing explicit, accessible information about both the constraints (e.g., limited parking) and the intended benefits (e.g., improved public space and better accessibility by alternative modes) can help set realistic expectations and reduce dissatisfaction.

Beyond one-way information provision, previous research has highlighted the importance of involving residents in the planning process. Even in large-scale projects like Merwede, it is important to foster a sense of ownership and agency at the sub-neighbourhood level. With a diverse mix of housing, residents will have varying needs and preferences. As already became apparent in Cartesius, residents' perception does not always align with what policy makers and developers expect, making it essential to integrate community input into the development process.

### Managing the temporary situation and optimising implementation order

The timing and order of policy implementation play a crucial role in shaping residents' perceptions and acceptance of low-car developments. In Cartesius, the absence of completed active mode infrastructure and the presence of temporary car parking in the public space made it difficult for residents to experience the intended benefits of a car-free environment. Although the neighbourhood was designed to prioritise active mobility and green public spaces, these elements were still largely absent at the time of the study, leading to dissatisfaction. Residents expressed frustration with temporary mobility conditions, highlighting the importance of delivering key improvements before enforcing car restrictions. These findings align with broader research, which suggests that the benefits of low-car policies should be in place from the outset to outweigh perceived inconveniences. Without immediate, tangible advantages such as high-quality pedestrian and cycling infrastructure or well-designed public spaces, dissatisfaction may increase, potentially undermining long-term support. To counteract resistance, policymakers should ensure that positive reinforcements accompany restrictive measures. In Cartesius, for instance, the provision of free shared-car trip minutes successfully encouraged shared mobility use, demonstrating that incentives can support behavioural change. Additionally, informal conversations with residents revealed strong anticipation for the planned green park, suggesting that visible improvements in public space could foster greater acceptance of low-car policies.

For future low-car developments, the planning and implementation process should be carefully reconsidered to minimise early negative perceptions. Some examples exist of developments where public greenery and infrastructure were completed before housing construction, allowing residents to immediately benefit from improved public spaces. This approach is especially important in low-car neighbourhoods. Future projects could adopt a similar strategy; ensuring that attractive, accessible public spaces and high-quality infrastructure for active modes are in place before introducing car restrictions.

For Cartesius specifically, improving the infrastructure for walking and cycling should be a key priority. Currently, the access road to the neighbourhood lacks any form of dedicated infrastructure for active modes. This has raised safety concerns among residents, as voiced during various conversations. The municipality has shown it can implement effective temporary measures for cyclists and pedestrians during roadworks in other parts of the city. A similar effort should be made here, even though Cartesius is not on a major through-route. Simple interventions such as clear signage, markings, or temporary paths could already make a significant difference.

### Policy persistence and enforcement

Despite initial dissatisfaction, the findings from Cartesius demonstrate that low-car policies can effectively reduce car ownership and use. However, early-stage dissatisfaction among residents could prompt policymakers to ease restrictions or make compromises, potentially undermining the effectiveness of the policy. Cartesius highlights the importance of persistence. While some residents reported

negative perceptions of mobility in the neighbourhood, dissatisfaction was primarily linked to temporary discomfort rather than fundamental accessibility problems. Research suggests that over time, reverse causality effects may lead to changing attitudes, as people gradually adapt to their new mobility environment. Instead of responding to complaints by relaxing policies, municipalities should allow sufficient time for behavioural adaptation to occur. At the same time, enforcement plays a critical role in maintaining policy integrity. In Cartesius, the presence of temporary free parking created frustration among both car owners and non-car owners; some residents disposed of their cars only to later discover that free parking was available (albeit temporarily), while others paid high fees for garage spaces while their neighbours parked for free in the public area. This highlights the need for a consistent and well-communicated enforcement strategy.

For Cartesius specifically, enforcing the existing parking policy is essential. The free parking lot in the middle of the neighbourhood is a major source of frustration for residents. Closing the barrier and charging the intended fees would align practice with policy. Beyond the local context, proper enforcement also supports the municipality's broader parking strategy. Parking management is more effective when applied consistently across the city, and Cartesius should not be an exception.

To ensure the long-term success of low-car developments, policymakers should consistently implement low-car measures and avoid modifying policies in response to initial dissatisfaction. This, however, does not mean enforcement should be rigidly imposed. It is crucial that the persistence and enforcement of policies are balanced with active resident engagement. While maintaining a long-term vision is essential, municipalities must also ensure that residents feel heard and that policies are adapted based on well-founded concerns rather than short-term resistance. As stated above, effective communication and public participation are key to the success of such developments.

To summarise, the findings of this research suggest that successful low-car developments require an approach in which effective communication, careful planning, and consistent enforcement are integrated.

# 7

# Discussion and future research

## 7.1. Limitations

### 7.1.1. Case-specific constraints and generalisability

The main limitations of this study are the small target group and its specific characteristics. Cartesius is a relatively small neighbourhood with only 322 households, of which 70 residents participated in the survey. Focusing on this single case, rather than comparing multiple neighbourhoods, allowed for a more in-depth understanding of the local context through case visits and informal conversations with residents, essentially 'becoming one with the case'. However, this also means the findings are specific to this unique setting and cannot be easily generalised.

While Cartesius can be seen as an example of the growing number of high-density, low-car, inner-city residential projects emerging in many cities, it does not serve as an empirically representative sample of such developments. The neighbourhood hosts a relatively homogeneous and specific group of residents, making it difficult to extrapolate findings to the general population. Though the presence of a significant number of non-self-selected residents provides a different context than often found in similar studies, this group still shares characteristics typically associated with low-car households. They are generally young, highly educated, environmentally conscious, and often without children; all factors commonly linked to car-free living and support for low-car neighbourhoods.

Additionally, the neighbourhood is still under development, which introduces strong contextual influences. The current living situation differs from what was initially planned, and many public spaces and mobility features are not yet completed. Furthermore, residents have only lived in Cartesius for a relatively short time, meaning the observed behavioural patterns are still evolving. The study, therefore, provides early insights into the effects of the low-car policy, but the results are not yet robust enough to predict long-term outcomes or be directly applied to other contexts or the broader population.

### 7.1.2. Reflection on Cartesius as case study area

The characteristics of the residents of Cartesius align with those often seen in low-car households. Even if some residents did not choose this neighbourhood specifically for its low-car design, they still fit the profile of people who are more likely to own fewer cars. Only four out of the seventy respondents said they were not using public transport before moving, which raises the question: how non-self-selected are these residents really? This suggests that Cartesius, with its population of high potential low-car residents, might not be the most neutral case for studying this dynamic. Looking at the reported mobility behaviour, we see a notable level of flexibility. Many residents use different modes of transport, a lot of active mobility, and car ownership was already low before the move. These findings indicate that the neighbourhood attracts residents who already travel in line with the low-car concept, which might lead to an overestimation of the positive perceptions of the mobility measures.

However, when it comes to behaviour change, these characteristics can cause both under- and overestimation. Underestimation might occur because many residents were already using sustainable modes,

leaving less room for visible change after moving. On the other hand, overestimation could happen if these residents, being more open to sustainable mobility, are particularly motivated to adjust their behaviour in line with the neighbourhood's goals.

The temporary situation of the neighbourhood adds another layer of complexity. The presence of a free parking area, meant as a temporary measure, makes it questionable whether Cartesius can truly be considered a low-car neighbourhood. Dissatisfaction with mobility-related aspects might stem more from this unfinished state than from fundamental issues with the low-car concept itself. While the current situation is not ideal, some initial effects of the parking policy are already visible, with residents giving up cars despite the free parking.

Overall, Cartesius provides valuable insights into low-car neighbourhoods and the role of self-selection. Its demographic profile and temporary state of development make it a less-than-perfect case, but given the limited availability of such neighbourhoods, it remains a relevant and informative study area. Cartesius offers a unique opportunity to study non-self-selected residents in a real-world low-car environment: an emerging dynamic with little empirical research. While no ideal case exists, this reflects the novelty of low-car developments, as municipalities are still experimenting with the concept.

### 7.1.3. Participation bias

Participation bias plays a role in this study, influencing the composition of the survey sample. The data shows an over-representation of car owners compared to the overall neighbourhood population, which likely led to a higher share of non-self-selected residents in the sample—those whose preferences do not align with the low-car concept. At the same time, the survey may have also attracted residents who strongly support the low-car concept, as advocates for such policies might have felt more inclined to participate. The true distribution of opinions and mobility behaviours in the neighbourhood may therefore be less polarised than the results suggest

This tendency for individuals with strong opinions, whether positive or negative, to engage in the survey is reflected in responses to the preferred living scenario question. It was expected that the middle-ground option would be the most popular, yet fewer than a quarter of respondents ranked it as their top choice. Instead, most residents either preferred a traditional, car-oriented neighbourhood or fully embraced the low-car concept. This pattern contrasts with findings in literature and real-world examples, where visually car-free neighbourhoods are generally well received (Nieuwenhuijsen et al. 2019).

Given the higher proportion of car owners in the sample, the actual share of non-self-selected residents in Cartesius is likely somewhat lower than estimated. Car ownership appears to be a key determinant in self-selection classification, meaning that the estimated 30/40 division could be reversed. However, even under this scenario, a substantial portion of Cartesius residents would still be classified as non-self-selected. While the exact proportion remains uncertain, the broader conclusion holds: non-self-selected residents do inhabit low-car neighbourhoods, a key consideration for future planning and policy.

## 7.2. Discussion of results

### 7.2.1. Causality and behavioural change

It is difficult to determine to what extent residents' mobility patterns are influenced by living in the low-car neighbourhood. The causal relationship is addressed by asking residents about their behaviour before and after relocation. However, other factors also play a role, such as moving closer to work or life changes like transitioning from being a student to having a job, all of which affect mobility patterns. As discussed in the literature chapter, the 'window of opportunity' refers to a disruption of travel habits caused by relocation. This effect might be limited for Cartesius residents, as two-thirds of the sample had previously lived in Utrecht, with 30% having lived in city centres or highly urbanised areas. This suggests that many residents may not have had to significantly adapt their mobility behaviour. When the built environment or level of urbanity remains similar, there is less incentive to rethink mobility habits. Although this may reduce the extent of behavioural change, it strengthens the argument that the low-car concept itself has influenced residents' behaviour, as other environmental factors remained constant.

Causality was also difficult to establish when looking at reduced car use and increased use of alterna-

tive modes. Understanding these substitution effects is crucial for policymakers but is highly context-dependent. Existing literature offers potential relationships between reduced car use and increased reliance on public transport, cycling, or shared mobility, but no direct causal link can be established from the Cartesius data. Did the new environment trigger people to use alternative modes, leading to a decrease in car use as a result, or vice versa; did moving to the neighbourhood in the first place mean reduced car use, and then people started to use other modes to replace it? Although this distinction would be valuable for policymakers, the key finding of this study remains unchanged: car use declined while alternative mobility modes increased, demonstrating the effectiveness of the low-car neighbourhood in achieving these outcomes, regardless of the exact causal sequence.

A final consideration concerns the relationship between relocating to Cartesius and car disposal. Various factors beyond the neighbourhood's low-car concept, such as moving closer to work or moving in with a partner who owns a car, could explain why some residents gave up their vehicles. However, the fact that all residents who disposed of a car cited limited parking as a contributing factor supports the effectiveness of the parking policy. Still, evaluating the policy's impact is not straightforward. There are spillover effects visible, undermining the policy, or at least revealing unwanted side effects of the policy. As well as the presence of the temporary parking facility which cannot be ignored. However, this does not necessarily weaken the policy's impact, this actually strengthens the case; despite this free parking area, people still have said they got rid of a car because of limited parking place.

### 7.2.2. Influence of the built environment on resients' travel behaviour

Recalling the framework from Figure 3.1, this study reinforces the argument that the built environment can exert a stronger influence on travel behaviour than personal attitudes alone. Consistent with previous research (Cao, P. L. Mokhtarian, and S. L. Handy 2009; Ewing and Cervero 2010; Naess 2014), the findings show that neighbourhood design has an independent effect on mobility patterns. By distinguishing between self-selected and non-self-selected residents, this study further examined the role of residential self-selection in shaping travel behaviour. Notably, the results suggest that the impact of self-selection may be limited. The similarities between the two groups in terms of travel adaptation and satisfaction with the neighbourhood's mobility measures indicate that the influence of the built environment can override pre-existing attitudes. This finding contributes to the broader body of literature on how urban design can shape behaviour beyond initial preferences. Additionally, the high number of non-self-selected residents in Cartesius challenges the fundamental assumption of self-selection theory—that individuals choose environments aligned with their travel attitudes. However, practical constraints, such as housing availability, clearly play a role in determining residential choice.

While behaviour can change relatively quickly in response to a new setting, attitudes often take longer to shift (S. Handy, Cao, and P. Mokhtarian 2005). The reverse causality theory described by Kroesen (2019) and Coevering et al. (2016) suggests that changes in travel behaviour can, over time, lead to shifts in attitudes. This study, however, captures only a snapshot in time, during the window of opportunity, but the slower process of adapting to the built environment is likely still ongoing. Evidence of this is found in the number of residents considering giving up their cars. Over time, more residents may further adapt, not only in terms of behaviour but also through shifts in attitude due to reverse causality effects. This could lead to a further decline in car ownership rates.

An important point to consider is that many current Cartesius residents may not stay long-term. The neighbourhood is home to many young people, and as a rental area, it is likely that highly educated, high-earning residents will move on to buy homes in the near future. The absence of children also suggests that residents might relocate when starting families. Some residents may be content with Cartesius for now, but envision a future in suburban homes with cars and gardens. This also has an effect on the classification of people in self-selected and non-self-selected groups. When asked about their preferred living situation, some might have interpreted this as a question about their ultimate future scenario rather than their current stage of life. While they may currently find a highly urban neighbourhood like Cartesius suitable, the lack of a specified time frame in the survey could mean that some respondents who prefer suburban living with cars are currently car-free and satisfied in Cartesius. This could result in an overestimation of residents classified as non-self-selected.

### 7.2.3. Reflection on quantifying the presence of residential self-selection

The classification of residents into self-selected and non-self-selected groups presents inherent challenges. There are multiple possible criteria for defining these categories, and this study adopted what seemed the most suitable approach for its objectives. However, the exact impact of residential self-selection remains difficult to quantify. The composition of these groups is not a definitive assessment of whether residents are self-selected or not, nor should the groupings be interpreted as precise judgments. However, the distinction between groups offers valuable insights. With all individuals categorised as non-self-selected either moved to Cartesius due to a lack of alternatives or exhibited some degree of misalignment between their preferences or travel behaviour and the neighbourhood's low-car mobility concept.

The clearest and most direct indicator of non-self-selection was when respondents explicitly stated that they moved to Cartesius because it was their only available option. However, this method likely underestimates the number of non-self-selected residents. The multiple-choice responses in the survey primarily reflected practical reasons for relocation, such as moving in with a partner or for work. Not all respondents who passively accepted a home in Cartesius selected the 'other' option to clarify that they had not deliberately chosen the neighbourhood. A total of 18 respondents provided such explanations, but the true number of non-self-selected residents may be higher. Since the question was not asked directly, this figure represents only those who took the initiative to specify their situation.

It was striking to see such a large number of residents voluntarily explain that Cartesius was not a deliberate choice. This result was not directly anticipated but offers valuable insights. More than a quarter of respondents explicitly mentioned that they had moved to Cartesius out of necessity, even though the survey did not prompt them to do so. This strongly reinforces the study's key finding that non-self-selected residents are increasingly moving into low-car neighbourhoods. Additionally, the proportion of non-self-selected residents in Cartesius turned out to be higher than expected. While no previous studies have directly quantified self-selection in such neighbourhoods, making comparisons difficult, existing literature suggests that self-selection rates are typically much higher. In similar contexts, most residents were already living car-free before relocating (Nobis 2003; Scheurer 2001; Späth and Ornetzeder 2017), or they actively sought out a car-free community that aligned with their existing lifestyle (Baehler and Rérat 2022; Foletta and Field 2011; Kushner 2005).

It is worth noting that the term 'self-selected residents' may be somewhat misleading. This group has not necessarily chosen Cartesius proactively; rather, it is simply the group that I did not classify as non-self-selected, making it, in essence, a 'residual' category. This naming could cause confusion if readers focus only on the results and assume that exactly 30 residents actively self-selected into the neighbourhood. However, these labels effectively highlight the distinction between the groups. They should be understood as descriptive markers rather than rigid definitions of the residents within each group.

Within the non-self-selected group, a subgroup can be identified; those whose mobility style happens to align with the neighbourhood's concept purely by chance. Despite not actively choosing Cartesius for its mobility model, they find that the neighbourhood suits their travel behaviour exceptionally well. In this sense, they were fortunate to end up in an environment that fits their lifestyle. While they are not self-selected, the outcome is the same: they do not experience dissonance because their mobility habits naturally align with the neighbourhood's low-car concept. This subgroup influences the overall findings in a notable way. Since their travel patterns already align with the neighbourhood's design, they likely contribute to more positive perceptions of the mobility measures. Their presence may create the impression that non-self-selected residents, in general, adapt well to the low-car concept. However, this effect is nuanced, as the majority of non-self-selected residents in the study were identified based on residential dissonance. As a result, while the presence of this subgroup may slightly overestimate the policy's effectiveness, the broader conclusion remains valid: low-car neighbourhoods can foster shifts in travel behaviour even among residents with differing initial attitudes.

### 7.2.4. Reported dissatisfaction among residents

Across the survey sample, a significant level of dissatisfaction is observed regarding various aspects of the neighbourhood and its mobility provisions. A particularly striking statistic is that more than half of

the respondents feel at least somewhat hindered in their mobility, reporting that their mobility needs are not met by the neighbourhood. However, the exact implications of this dissatisfaction remain unclear. Does it mean that residents cannot carry out their daily activities? Is their accessibility compromised, or are these merely inconveniences? Since this study did not specifically measure accessibility or perceived accessibility, no definitive conclusions can be drawn. Nevertheless, the findings suggest that these negative responses might not be as alarming as they initially seem. Residents of Cartesius demonstrate a high degree of multi-modal behaviour, with no clear signs of dependence on a single transport mode. Additionally, the overall satisfaction with living in Cartesius remains relatively high, which indicates that potential mobility-related challenges do not significantly detract from their overall residential experience. Insights from resident interviews further indicate that much of the discontent relates more to inconvenience than to fundamental mobility problems. While there are valid complaints, their severity appears to remain within reasonable bounds.

Part of the dissatisfaction can be attributed to residents experiencing a mismatch between their mobility preferences and the neighbourhood's design. For instance, some individuals would prefer abundant parking spaces and the freedom to own multiple cars; needs that are not accommodated within Cartesius' mobility concept. On the other hand, Cartesius is currently also not really facilitating active mode users, with the absence of infrastructure for these modes. Which further explains why dissatisfaction with mobility should not be taken as evidence against the low-car concept itself but rather as a signal that implementation strategies need improvement.A takeaway from the literature is that the financial savings from not constructing parking spaces should ideally be reinvested into the neighbourhood, providing visible benefits for residents. These benefits could be mobility-related but could also support other community priorities. In Cartesius, however, the money saved from reduced parking infrastructure appears to have been factored into rental prices, making the financial advantage largely invisible to residents. As a result, they currently experience only the restrictive aspects of the policy without perceiving its direct benefits. As a result, they experience the restrictive aspects of the policy without perceiving its direct benefits. While the survey results initially seemed overwhelmingly negative, the absence of visible benefits and the presence of restrictions make it unsurprising that residents expressed such high levels of dissatisfaction. The conversations with residents further toned it down and made it understandable why the survey results were so negative. With dissatisfaction attributed to practical and temporary aspects, it is expected to improve in the near future, as for example the neighbourhood's green public space will be realised.

## 7.3. Recommendations for future research

### Conduct longitudinal studies to capture behaviour change

Future research should employ longitudinal studies to track residents' behaviour over several years, examining whether initial adaptations become permanent and how attitudes toward low-car living evolve. The case study of Cartesius provides a snapshot of mobility adaptation in a low-car neighbourhood shortly after residents moved in. However, mobility behaviour evolves over time, and a longer-term perspective is needed to understand whether changes in car ownership and travel habits persist or revert. To fully capture changes in travel-related attitudes, participants should be followed over a longer period. Monitoring residential mobility patterns over time might also shed light on whether residents choose to move again instead of adapting to the low-car setting. A follow-up study in Cartesius would be really valuable, especially after the initial implementation phase, during which temporary contextual factors strongly influenced residents' satisfaction. It is crucial to examine what happens once the full mobility concept is rolled out.

### Investigate mobility adaption in a more diverse population

Another important direction for future research is to investigate the experiences and behaviours of a broader, more diverse population. This study made an initial step by examining a case with a more varied group of residents compared to the typical self-selected population of car-free supporters. However, the sample still represented a relatively homogeneous group. To better understand the dynamics of individuals who move to low-car neighbourhoods without actively choosing this lifestyle, future research should include populations that more accurately reflect the general public. While stated preference studies have provided some insights, they have limitations in capturing real-life behaviour and adaptation. The study of Cartesius showed that non-self-selected residents do end up in low-car neigh-

bourhoods, underlining the importance of researching this dynamic. As cities continue to implement such developments, it is crucial to investigate whether these neighbourhoods can still have the intended effects on the broader population and whether this group is also able to adapt their mobility patterns. In this context, it will be particularly important to measure accessibility in future studies to ensure these neighbourhoods do not create fundamental mobility problems.

### Further investigation into residential self-selection

Further methodological research is needed to better understand and quantify the role of residential self-selection in low-car neighbourhoods. This thesis used a group-comparison approach to distinguish between self-selected and non-self-selected residents, but this is just one way of doing so. Future studies should continue refining approaches to measuring self-selection, potentially through alternative grouping techniques or more advanced statistical models. A more precise understanding of self-selection effects would contribute to more accurate assessments of the causal relationships between the built environment and mobility behaviour, particularly in the unique context of low-car neighbourhoods. Understanding the role of residential self-selection remains a key factor in interpreting the success of these neighbourhoods.

# References


Antonson, Hans, Robert Hrelja, and Per Henriksson (2017). “People and parking requirements: Residential attitudes and day-to-day consequences of a land use policy shift towards sustainable mobility”. In: *Land Use Policy* 62, pp. 213–222. ISSN: 0264-8377. DOI: https://doi.org/10.1016/j.landusepol.2016.12.022. URL: https://www.sciencedirect.com/science/article/pii/S0264837716304975.

Baehler, Daniel (2019). “Living in a car-free housing developmen. Motivations and mobility practices of residents in nine developments in Switzerland and Germany”. PhD thesis. Université de Lausanne, Faculté des géosciences et de l’environnement.

Baehler, Daniel and Patrick Rérat (2022). “Beyond the car. Car-free housing as a laboratory to overcome the “system of automobility””. In: *Applied mobilities* 7.3, pp. 280–297.

Bagley, Michael N and Patricia L Mokhtarian (2002). “The impact of residential neighborhood type on travel behavior: A structural equations modeling approach”. In: *The Annals of regional science* 36, pp. 279–297.

Bamberg, Sebastian (2006). “Is a residential relocation a good opportunity to change people’s travel behavior? Results from a theory-driven intervention study”. In: *Environment and behavior* 38.6, pp. 820–840.

Banister, David (2008). “The sustainable mobility paradigm”. In: *Transport policy* 15.2, pp. 73–80.

Becker, Henrik, Francesco Ciari, and Kay W Axhausen (2017). “Comparing car-sharing schemes in Switzerland: User groups and usage patterns”. In: *Transportation Research Part A: Policy and Practice* 97, pp. 17–29.

Bohte, Wendy (2010). *Residential self-selection and travel: The relationship between travel-related attitudes, built environment characteristics and travel behaviour*. Vol. 35. IOS Press.

Borgers, Aloys et al. (2008). “Preferences for car-restrained residential areas”. In: *Journal of Urban Design* 13.2, pp. 257–267.

Borges, Bruno Franco Da Silva and Lenise Grando Goldner (2015). “Implementation of car-free neighbourhoods in medium-sized cities in Brazil, a case study in Florianópolis, Santa Catarina”. In: *International Journal of Urban Sustainable Development* 7.2, pp. 183–195.

Cao, Xinyu and Daniel Chatman (2016). “How will smart growth land-use policies affect travel? A theoretical discussion on the importance of residential sorting”. In: *Environment and Planning B: Planning and Design* 43.1, pp. 58–73.

Cao, Xinyu, Patricia L Mokhtarian, and Susan L Handy (2009). “Examining the impacts of residential self-selection on travel behaviour: a focus on empirical findings”. In: *Transport reviews* 29.3, pp. 359–395.

CBS (June 2024). *Huishoudens; samenstelling, grootte, regio, 1 januari*. URL: https://www.cbs.nl/nl-nl/cijfers/detail/71486ned.

Cervero, Robert (2002). “Induced travel demand: Research design, empirical evidence, and normative policies”. In: *Journal of Planning Literature* 17.1, pp. 3–20.

Cervero, Robert and Jennifer Day (2008). “Residential relocation and commuting behavior in Shanghai, China: the case for transit oriented development”. In.

Christiansen, Petter et al. (2017). “Parking facilities and the built environment: Impacts on travel behaviour”. In: *Transportation Research Part A: Policy and Practice* 95, pp. 198–206.

Clark, Ben et al. (2014). “Life events and travel behavior: exploring the interrelationship using UK household longitudinal study data”. In: *Transportation Research Record* 2413.1, pp. 54–64.

Coevering, Paul van de et al. (2016). “Causal effects of built environment characteristics on travel behaviour: a longitudinal approach”. In: *European Journal of Transport and Infrastructure Research* 16.4.

Crawford, James Homer (2000). *Carfree cities*.

Creutzig, Felix et al. (2020). “Fair street space allocation: ethical principles and empirical insights”. In: *Transport Reviews* 40.6, pp. 711–733.

CROW (Apr. 2021). *Leidraad parkeren bij knooppunten en mobiliteitshubs*. Tech. rep.

Dagblad van het Noorden, - (Apr. 2024). “Anne en Daan betalen in het autoluwe Ebbingekwartier tien keer zoveel parkeergeld als andere Stadjers. ’We zijn geen pinautomaat!’” In: URL: https://dvhn.nl/groningen/stad/Bewoners-autoluw-Ebbingekwartier-betalen-tien-keer-zoveel-parkeergeld-als-andere-Stadjers-29002920.html.

De Vos, Jonas, Dick Ettema, and Frank Witlox (2018). “Changing travel behaviour and attitudes following a residential relocation”. In: *Journal of Transport Geography* 73, pp. 131–147.

Dijk, Marc, Moshe Givoni, and Karen Diederiks (2018). “Piling up or packaging policies? An ex-post analysis of modal shift in four cities”. In: *Energies* 11.6, p. 1400.

Dillman, Don A, Jolene D Smyth, and Leah Melani Christian (2014). *Internet, phone, mail, and mixed-mode surveys: The tailored design method*. John Wiley & Sons.

Doheim, Rahma M, Alshimaa Aboelmakarem Farag, and Samaa Badawi (2020). “Success measures for transforming into car-free cities: Recommendations for implementation”. In: *Humanizing cities through car-free city development and transformation*, pp. 231–267.

EEA (2020). *The first and last mile—the key to sustainable urban transport*.

Elldér, Erik, Katarina Haugen, and Bertil Vilhelmson (2022). “When local access matters: A detailed analysis of place, neighbourhood amenities and travel choice”. In: *Urban Studies* 59.1, pp. 120–139.

England, EMILY and ELIN Eriksson (2020). “Achieving Long-Term Social Sustainability Through Car-Free Development”. MA thesis. CHALMERS UNIVERSITY OF TECHNOLOGY.

Ewing, Reid and Robert Cervero (2010). “Travel and the built environment: A meta-analysis”. In: *Journal of the American planning association* 76.3, pp. 265–294.

Foletta, Nicole and Simon Field (2011). “Europe’s vibrant new low car (bon) communities”. In: *ITDP, New York*.

Foletta, Nicole and Jason Henderson (2016). *Low Car (bon) Communities: Inspiring car-free and car-lite urban futures*. Routledge.

Gärling, Tommy and Geertje Schuitema (2007). “Travel demand management targeting reduced private car use: effectiveness, public acceptability and political feasibility”. In: *Journal of social issues* 63.1, pp. 139–153.

Gehl, Jan (2013). *Cities for people*. Island press.

Gemeente Utrecht, - (n.d.). *Parkeerkosten | gemeente Utrecht*. URL: http://utrecht.nl/wonen-en-leven/parkeren/parkeerkosten.

Gonzalez, Juan Nicolas et al. (2021). “What impact do private vehicle restrictions in urban areas have on car ownership? Empirical evidence from the city of Madrid”. In: *Cities* 116, p. 103301.

Goudappel Coffeng BV, - (Jan. 2020). *Parkeren en verkeersgeneratie Cartesiusdriehoek Fase 1*. Tech. rep. URL: https://www.planviewer.nl/imro/files/NL.IMRO.0344.BPCARTSIUSDRIFASE1-ON01/b_NL.IMRO.0344.BPCARTSIUSDRIFASE1-ON01_tb4.pdf.

Guo, Zhan (2013). “Home parking convenience, household car usage, and implications to residential parking policies”. In: *Transport policy* 29, pp. 97–106.

Hahn, Rüdiger et al. (2020). ““I like it, but I don’t use it”: Impact of carsharing business models on usage intentions in the sharing economy”. In: *Business Strategy and the Environment* 29.3, pp. 1404–1418.

Handy, Susan, Xinyu Cao, and Patricia Mokhtarian (2005). “Correlation or causality between the built environment and travel behavior? Evidence from Northern California”. In: *Transportation Research Part D: Transport and Environment* 10.6, pp. 427–444.

Hiscock, Rosemary et al. (2002). “Means of transport and ontological security: Do cars provide psycho-social benefits to their users?” In: *Transportation Research Part D: Transport and Environment* 7.2, pp. 119–135.

Höjemo, Thomas (2015). “Better Living Quality with Carfree Urban Areas?” In: *IX Semanas de Políticas Públicas, 2015*. Universidade Tecnológica Federal do Paraná.

Hrelja, Robert and Tom Rye (2023). “Decreasing the share of travel by car. Strategies for implementing ‘push’or ‘pull’measures in a traditionally car-centric transport and land use planning”. In: *International Journal of Sustainable Transportation* 17.5, pp. 446–458.

Ison, Stephen G and Corinne Mulley (2014). *Parking: issues and policies*. Emerald Group Publishing.

Johansson, Fredrik, Greger Henriksson, and Pelle Envall (2019). “Moving to private-car-restricted and mobility-served neighborhoods: The unspectacular workings of a progressive mobility plan”. In: *Sustainability* 11.22, p. 6208.

Jones, Peter (2014). “The evolution of urban mobility: The interplay of academic and policy perspectives”. In: *IATSS research* 38.1, pp. 7–13.

Jorritsma, Peter et al. (Oct. 2021). *Deelauto- en deelfietsmobiliteit in Nederland Ontwikkelingen*. Tech. rep.

Kampert, A et al. (2017). “Nederlanders en hun auto: Een overzicht van de afgelopen tien jaar”. In: *Den Haag: CBS*.

Kennisinstituut voor Mobiliteitsbeleid, - (Feb. 2022). *De maatschappelijke effecten van het wijdverbreide autobezit in Nederland.* Tech. rep. Den Haag, nl.

Kent, Jennifer L and Robyn Dowling (2018). “Commercial car sharing, complaints and coping: does sharing need willingness?” In: *Urban policy and research* 36.4, pp. 464–475.

Klein, Marcus, Thomas Klinger, and Martin Lanzendorf (2024). “Residential self-selection and the relative importance of travel considerations in the residential choice of a car-reduced neighbourhood”. In: *Transportation Research Part A: Policy and Practice* 190, p. 104266.

Klöckner, Christian (2004). “How single events change travel mode choice: A life span perspective”. In.

Knapen, Luk et al. (Jan. 2021). “An Activity Based integrated approach to model impacts of parking, hubs and new mobility concepts”. In: *Procedia Computer Science* 184, pp. 428–437. DOI: 10.1016/j.procs.2021.03.054. URL: https://doi.org/10.1016/j.procs.2021.03.054.

Krizek, Kevin J (2003). “Residential relocation and changes in urban travel: Does neighborhood-scale urban form matter?” In: *Journal of the American planning association* 69.3, pp. 265–281.

Kroesen, Maarten (2019). “Residential self-selection and the reverse causation hypothesis: Assessing the endogeneity of stated reasons for residential choice”. In: *Travel Behaviour and Society* 16, pp. 108–117.

Kroesen, Maarten and GP van Wee (2021). “Autobezit en autogebruik onder jongeren en visies ten aanzien van deelmobiliteit”. In.

Kushner, James A (2005). “Car-Free housing developments: Towards sustainable smart growth and urban regeneration through car-free zoning, car-free redevelopment, pedestrian improvement districts, and new urbanism”. In: *UCLA J. Envtl. L. & Pol’y* 23, p. 1.

Kuss, Paula and Kimberly A Nicholas (2022). “A dozen effective interventions to reduce car use in European cities: Lessons learned from a meta-analysis and transition management”. In: *Case studies on transport policy* 10.3, pp. 1494–1513.

Lin, En-Yi et al. (2017). “Social and built-environment factors related to children’s independent mobility: the importance of neighbourhood cohesion and connectedness”. In: *Health & place* 46, pp. 107–113.

Maat, Cornelis (2009). *Built environment and car travel: Analyses of interdependencies*. 29. IOS Press.

Manderscheid, Katharina (2014). “Formierung und Wandel hegemonialer Mobilitätsdispositive: automobile Subjekte und urbane Nomaden”. In.

Marsden, Greg (2006). “The evidence base for parking policies—a review”. In: *Transport policy* 13.6, pp. 447–457.

McCahill, Christopher T and Norman W Garrick (2010). “Influence of parking policy on built environment and travel behavior in two New England cities, 1960 to 2007”. In: *Transportation Research Record* 2187.1, pp. 123–130.

Meester, R (2021). “Evaluation of trip characteristics and accessibility in car-free development: a case study in the Merwedekanaalzone in Utrecht”. MA thesis. University of Twente.

Melia, S (2009). “Potential for Car Free Development in the UK (Ph. D. Thesis)”. In: *University of the West of England, Bristol*.

Melia, Steve, Graham Parkhurst, and Hugh Barton (2010). “Carfree, Low-car–What’s the Difference?” In: *World Transport Policy & Practice* 16.2.

Mingardo, Giuliano, Bert Van Wee, and Tom Rye (2015). “Urban parking policy in Europe: A conceptualization of past and possible future trends”. In: *Transportation Research Part A: Policy and Practice* 74, pp. 268–281.

Müller, Miriam and Prof Oscar Reutter (2022). “Course change: Navigating urban passenger transport toward sustainability through modal shift”. In: *International Journal of Sustainable Transportation* 16.8, pp. 719–743.

Næss, Petter (2009). “Residential self-selection and appropriate control variables in land use: Travel studies”. In: *Transport Reviews* 29.3, pp. 293–324.

Naess, Petter (2014). “Tempest in a teapot: The exaggerated problem of transport-related residential self-selection as a source of error in empirical studies”. In: *Journal of transport and land use* 7.3, pp. 57–79.

Nash, Chris and John Whitelegg (2016). “Key research themes on regulation, pricing, and sustainable urban mobility”. In: *International Journal of Sustainable Transportation* 10.1, pp. 33–39.

Newman, Peter and Jeffrey Kenworthy (1998). *Sustainability and cities: overcoming automobile dependence*. Island Press.

Nies, Carmel (2020). “Car owners’ willingness to reside in a car restricted residential area - A stated choice experiment to assess the effect of parking arrangements and the physical environment on the willingness of car owners to move to a car restricted residential area”. MA thesis. Delft University of Technology.

Nieuwenhuijsen, Mark et al. (2019). “Implementing Car-Free Cities: Rationale, Requirements, Barriers and Facilitators”. In: *Integrating Human Health into Urban and Transport Planning: A Framework*. Ed. by Mark Nieuwenhuijsen and Haneen Khreis. Cham: Springer International Publishing, pp. 199–219. ISBN: 978-3-319-74983-9. DOI: 10.1007/978-3-319-74983-9_11. URL: https://doi.org/10.1007/978-3-319-74983-9_11.

Nijland, Hans and Jordy van Meerkerk (2017). “Mobility and environmental impacts of car sharing in the Netherlands”. In: *Environmental Innovation and Societal Transitions* 23, pp. 84–91.

Nobis, Claudia (2003). “The impact of car-free housing districts on mobility behaviour-case study”. In: *WIT Transactions on Ecology and the Environment* 67.

Oakil, Abu Toasin Md, Dorien Manting, and Hans Nijland (2016). “Determinants of car ownership among young households in the Netherlands: The role of urbanisation and demographic and economic characteristics”. In: *Journal of transport geography* 51, pp. 229–235.

Ornetzeder, Michael et al. (2008). “The environmental effect of car-free housing: A case in Vienna”. In: *Ecological Economics* 65.3, pp. 516–530.

Preston, Carolyn C and Andrew M Colman (2000). “Optimal number of response categories in rating scales: reliability, validity, discriminating power, and respondent preferences”. In: *Acta Psychologica* 104.1, pp. 1–15. ISSN: 0001-6918. DOI: https://doi.org/10.1016/S0001-6918(99)00050-5. URL: https://www.sciencedirect.com/science/article/pii/S0001691899000505.

Rye, Tom and Robert Hrelja (2020). “Policies for reducing car traffic and their problematisation. Lessons from the mobility strategies of British, Dutch, German and Swedish cities”. In: *Sustainability* 12.19, p. 8170.

Rye, Tom and Till Koglin (2014). “Parking management”. In: *Parking issues and policies*. Emerald Group Publishing Limited, pp. 157–184.

Scheiner, Joachim and Christian Holz-Rau (2013). “A comprehensive study of life course, cohort, and period effects on changes in travel mode use”. In: *Transportation Research Part A: Policy and Practice* 47, pp. 167–181.

Scheurer, Jan (2001). “Residential Areas for Households without Cars: The Scope for Neighbourhood Mobility Management in Scandinavian Cities”. In: *Proceedings from the Annual Transport Conference at Aalborg University*. Vol. 8. 1.

Scheurer, Jan and Peter Newman (Jan. 2009). “Vauban: A European Model Bridging the Green and Brown Agendas”. In.

Schwanen, Tim and Patricia L Mokhtarian (2005). “What affects commute mode choice: neighborhood physical structure or preferences toward neighborhoods?” In: *Journal of transport geography* 13.1, pp. 83–99.

Selzer, Sina (2021). “Car-reduced neighborhoods as blueprints for the transition toward an environmentally friendly urban transport system? A comparison of narratives and mobility-related practices in two case studies”. In: *Journal of Transport Geography* 96, p. 103126. ISSN: 0966-6923. DOI: https://doi.org/10.1016/j.jtrangeo.2021.103126. URL: https://www.sciencedirect.com/science/article/pii/S0966692321001794.

Selzer, Sina and Martin Lanzendorf (2019). “On the road to sustainable urban and transport development in the automobile society? Traced narratives of car-reduced neighborhoods”. In: *Sustainability* 11.16, p. 4375.

Selzer, Sina and Martin Lanzendorf (2022). “Car independence in an automobile society? The everyday mobility practices of residents in a car-reduced housing development”. In: *Travel behaviour and society* 28, pp. 90–105.

Seto, Karen C, Burak Güneralp, and Lucy R Hutyra (2012). “Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools”. In: *Proceedings of the National Academy of Sciences* 109.40, pp. 16083–16088.

Shaheen, Susan et al. (2020). “Sharing strategies: carsharing, shared micromobility (bikesharing and scooter sharing), transportation network companies, microtransit, and other innovative mobility modes”. In: *Transportation, land use, and environmental planning*. Elsevier, pp. 237–262.

Sheller, Mimi and John Urry (2000). “The city and the car”. In: *International journal of urban and regional research* 24.4, pp. 737–757.

Shoup, Donald (2018). *Parking and the City*. Routledge.

Smith, G, J Sochor, and IM Karlsson (n.d.). *Adopting Mobility-as-a-Service: An empirical analysis of end-users’ experiences. Travel Behaviour and Society 2022, 28, 237-248*.

Späth, Philipp and Michael Ornetzeder (2017). “From building small urban spaces for a car-free life to challenging the global regime of automobility: Cases from Vienna and Freiburg”. In: *Urban sustainability transitions*. Routledge, pp. 191–209.

Sprei, Frances et al. (2020). “Review of the effects of developments with low parking requirements”. In: *Sustainability* 12.5, p. 1744.

Stake, Robert (1995). *Case study research*. Springer.

Stanbridge, Karen, Glenn Lyons, and Stuart Farthing (2004). “Travel behaviour change and residential relocation”. In: *3rd international conference of traffic and transport psychology, Nottingham*, pp. 5–9.

Thaler, Richard H (2008). “Nudge: Improving Decisions About Health”. In: *Wealth, and Happiness* 3.

Thomsen, Judith and Erica Löfström (2011). “How to arrange for car-free living? Perspectives of future residents of a carbon-neutral housing area on non-motorized transport and car use”. In: *Proceedings of the ECEEE*, pp. 6–11.

Timmermans, Harry et al. (2003). “Spatial context and the complexity of daily travel patterns: an international comparison”. In: *Journal of Transport Geography* 11.1, pp. 37–46.

Toersche, Lotte (2023). “The car-free neighbourhood. A neighbourhood for all? Exploring the Perceptions and Challenges of Car-Free Neighbourhoods: A Comparative Case Study in Zwolle and Groningen, the Netherlands”. MA thesis. University of Groningen.

Topp, Hartmut and Tim Pharoah (1994). “Car-free city centres”. In: *Transportation* 21, pp. 231–247.

Tourangeau, Roger (2000). “The psychology of survey response”. In: *University of Cambridge*.

United Nations, - (2023). “— SDG indicators”. In: URL: `https://unstats.un.org/sdgs/report/2023/goal-11/`.

Urry, John (2004). “The ‘system’of automobility”. In: *Theory, culture & society* 21.4-5, pp. 25–39.

Utrecht, Gemeente (Dec. 2021). *Parkeerbeleid fiets en auto | gemeente Utrecht*. URL: `https://omgevingsvisie.utrecht.nl/thematisch-beleid/parkeren`.

Utrecht in Cijfers, - (2024). *Utrecht in cijfers*. URL: `https://utrecht.incijfers.nl/`.

Van Ommeren, Jos, Derk Wentink, and Jasper Dekkers (2011). “The real price of parking policy”. In: *Journal of Urban Economics* 70.1, pp. 25–31.

Van Wee, Bert (2009). “Self-selection: a key to a better understanding of location choices, travel behaviour and transport externalities?” In: *Transport reviews* 29.3, pp. 279–292.

Waerden, Peter van der and Harry Timmermans (2016). “Do parking measures contribute to a sustainable transportation system?” In: *Strategies for Sustainable Mobilities*. Routledge, pp. 129–140.

Wang, Fenglong and Donggen Wang (2020). “Changes in residential satisfaction after home relocation: A longitudinal study in Beijing, China”. In: *Urban Studies* 57.3, pp. 583–601.

Yin, RK (1994). “Case Study Research: Design and Methods (2nd edn). Thousand Oaks, CA: Sage”. In.

Zijlstra, T, J Witte, and S Bakker (Feb. 2022). *Verklaringen voor de verschillen in autobezit bij Nederlandse huishoudens.* Tech. rep.

OpenAI’s ChatGPT was used for textual enhancements

# A

# Scientific article

# The impact of low-car residential neighbourhoods on mobility behaviour: A case study of Cartesius in Utrecht from residents' perspectives

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**As cities are densifying, low-car neighbourhoods are increasingly seen as a solution to reduce car dependency, improve public space, and encourage alternative mobility options. This study examines the impact of such a development by evaluating the mobility behaviour and perceptions of residents in Cartesius, a newly developed low-car neighbourhood in Utrecht. Using a revealed preference approach, this research analyses survey data (N=70) and qualitative insights from conversations with residents to explore the influence of residential self-selection on mobility adaptation. Findings indicate that even non-self-selected residents—those who did not actively choose a low-car environment—reduce car ownership and car use while increasing reliance on public transport and shared mobility. This suggests that well-designed low-car policies can influence travel behaviour beyond pre-existing preferences. Meaning that large-scale low-car policies could be viable for a broader population beyond those who actively choose this lifestyle.**

**Keywords:** low-car neighbourhoods, residential self-selection, mobility behaviour

## I. Introduction

URBANISATION is accelerating rapidly worldwide, with an estimated 55% of the global population already living in urban areas [1]. This trend is expected to continue, placing immense pressure on cities to accommodate growing populations while maintaining quality of life. The demand for housing and services is driving densification, particularly in European cities where space is inherently scarce. This scarcity intensifies competition for land use, with private cars often dominating the urban landscape. In Dutch cities, infrastructure for cars consumes up to 50% of public space, and car users demand 3.5 times more physical space than non-car users [2], underscoring the inequities imposed on the broader population by car dependence [3, 4]. Beyond space constraints, private cars contribute significantly to environmental pressures [5–8]. Especially in dense urban areas, the presence of vehicles contributes to congestion, pollution, and a significant reduction in green space — all of which undermine efforts to create safe, healthy, and liveable cities [9, 10].

Traditional policies have prioritised private car use [11, 12], but there is growing recognition that this approach is unsustainable [13]. As cities become denser, the need for innovative urban mobility solutions becomes clear. Reducing car dependency is increasingly seen as essential not only for environmental sustainability but also for reclaiming urban space for people [14–16]. To address these issues, many cities are experimenting with low-car residential developments. These developments restrict car access, reduce parking availability, and promote alternative mobility options such as cycling, walking, and shared mobility services [17, 18]. However, the effectiveness of these policies depends not only on the physical design of the neighbourhood, but also on how residents perceive and adapt to the mobility restrictions [10].

This is particularly relevant given that most people do not want to give up their cars or be restricted in parking. The car offers a highly convenient and flexible mobility option, so removing or restricting cars cannot be done without careful consideration. Studies by [19] and [15] show that the majority of residents in four

Dutch cities prefer living in areas without car restrictions. Despite this seemingly resistant attitude of potential residents, these large scale urban low-car developments are rising everywhere - a shift in urban planning can be seen [20, 21]. Driven by the need for more houses within cities while maintaining liveability and accessibility, policy makers and urban planners decided that this leaves little to no room for private vehicles. One of the most famous Dutch current projects is Utrecht's Merwedekanaalzone, where homes for 12000 people are being built in a low-car residential area. This project has gained attention for its large scale and its approach to minimising car use. Neighbourhoods like this will attract a broad population with houses being built ranging from social housing to larger private homes. As [22] highlights, future projects will attract a broader population, not just those with pre-existing low-car lifestyles, making it essential to evaluate the effects on a larger scale.

Much of the existing research is limited to eco-villages or communities where residents already embrace car-free living, failing to capture the experiences of diverse populations [22, 23]. There is limited research on how residents with no initial intention of living without cars adapt to low-car neighbourhoods, a key gap this research aims to address. Understanding whether residents who may not have initially sought a car-free lifestyle also adjust their mobility habits provides insights into the effectiveness of low-car policies. Which is essential for evaluating the viability of these developments.

Furthermore, many studies focus on best-practice examples, often overlooking the complexities and challenges faced by residents in their daily lives. [20, 24–26] stress that evaluations based on observed behaviours, rather than stated preferences, are crucial for understanding the real impact of low-car policies. Minimal research exists on how low-car developments influence mobility patterns or on the preferences of residents in Dutch low-car areas [10].

This study addresses this research gap by taking a revealed preference approach to investigate how residents of low-car neighbourhoods perceive and adapt to sustainable mobility measures, and how their adaptation is influenced by residential self-selection. The main research question guiding this study is:

> *How do residents of low-car neighbourhoods **perceive** and **adapt** to the sustainable mobility measures, and how is this influenced by **residential self-selection**?*

Residential self-selection refers to the idea that individuals choose their living environment based on their pre-existing travel preferences and attitudes [26–28]. Understanding the role of residential self-selection is crucial for assessing the actual effectiveness of low-car neighbourhoods on travel behaviour. If low-car policies only work for those who already prefer a car-free lifestyle, their impact may be limited. However, if even non-self-selected residents adapt their behaviour in line with the goals of a low-car neighbourhood, this provides stronger evidence that the built environment itself can influence travel behaviour beyond individual attitudes [29–31]

### A. Case study description: Cartesius

Cartesius is a newly developed low-car neighbourhood in Utrecht. Cartesius was selected as the case study for this research because it provides a real-world setting to examine mobility measures in a low-car neighbourhood. As a newly developed, high-density urban area, it aligns with the growing trend of car-free and car-reduced residential developments in European cities. The neighbourhood offers a unique opportunity to assess how residents experience and adapt to low-car policies, particularly given the presence of both self-selected and non-self-selected residents.

The neighbourhood is part of a larger redevelopment project on a former Dutch Railways site and will eventually consist of 2,800 homes with various amenities. At the time of the study, Phase 1 of the development was completed, consisting of 322 mid-range rental apartments. Offering a sufficiently sized sample for

analysis. Although Cartesius is still under development, residents have been living there since April 2023, allowing for an initial assessment of mobility patterns and perception of the mobility concept.

Table 1 and 2 present the neighbourhood's relevant mobility policies and characteristics of the residents.

| **Policy measure** | **Description** |
|---|---|
| Parking restrictions | Low parking norm (0,18 spaces per household), no resident parking permits, no public parking |
| Car-free public space | Planned: streets for walking and cycling, lots of green, a park. Currently available: temporary parking space in the public area |
| Shared mobility | Planned: 1 shared car per 10 households (3000 in total at full development). Currently available: 4 shared cars |
| Mobility incentives | Planned: residents receive mobility credits for shared mobility and public transport through Cartesius-MaaS. Currently available: free shared car trip minutes |
| Public transport access | Located next to station Zuilen, 10 minutes cycling from Utrecht CS, bus stops within walking distance |
| Active modes | Currently available: no dedicated infrastructure for cycling, no safe walking or cycling routes to access neighbourhood |

**Table 1. Low-car policy measures in Cartesius**

| **Demographic indicator** | **Cartesius** |
|---|---|
| Total residents | 397 |
| Average household size | 1.2 |
| Household composition | 77% single-person household, 2% household with children |
| Age profile | 97% under 45, 63% under 29 |
| Education level | high |
| Car ownership | 70% car-free, 29% 1 car, 1% 2 or more cars |

**Table 2. Characteristics of the residents of Cartesius**

As the policies mentioned in Table 1 show, Cartesius aims to reduce car ownership and use among residents, making it a relevant case for studying the potential impacts of such measures. However, at the time of the study, much of the planned public space and mobility infrastructure was still under development, which influenced residents' experiences.

## II. Methodology

This study employed a case study approach to examine how residents of a low-car neighbourhood perceive and adapt to sustainable mobility measures. A mixed-methods approach was adopted, combining survey data with qualitative insights from resident conversations and on-site observations. This combination allowed for a comprehensive understanding of residents' mobility behaviour and experiences.

### A. Data collection

The primary data source for this study was an online survey targeting all current residents of Cartesius over 18 years old. The survey was distributed via the Cartesius resident communication app and physical flyers

with a QR code. Data collection occurred over two weeks in December 2024. A total of 70 responses were obtained, representing approximately 22% of the total households in Cartesius. Participation was voluntary and responses were anonymous.

The survey was constructed in Qualtrics, under a license of Delft University of Technology, and consisted of 25 closed-ended questions covering the following topics:

- Socio-demographic characteristics (e.g., age, household composition, education level)
- Mobility behaviour (e.g., car ownership, travel frequency by different modes, mobility habits before and after moving)
- Perceptions of mobility measures (e.g., satisfaction with parking, public transport accessibility, shared mobility offer)
- Attitudes towards mobility (e.g., transport mode preferences, sustainability importance)
- Residential self-selection and relocation motivations (e.g., reasons for choosing Cartesius, alignment with the low-car concept)

In addition to the survey, informal conversations with approximately 20 residents were conducted during a neighbourhood Christmas gathering. The relaxed setting encouraged open discussions, allowing residents to freely share their experiences, concerns, and opinions on mobility in Cartesius. Parking and transport frequently emerged as spontaneous discussion topics, reducing the risk of response bias that may occur in formal interviews. A passive observation approach was also adopted at times, allowing for candid insights without direct prompting. While these conversations were not recorded, detailed notes were taken immediately afterward, and all information was fully anonymised. Though not quantified, these qualitative insights provided a deeper understanding of resident experiences and complemented the survey findings.

**B. Data analysis**

Survey data were analysed using IBM SPSS Statistics and Microsoft Excel. Descriptive statistics summarised mobility behaviour trends and resident perceptions. Chi-square tests were used to analyse relationships between variables. To assess behavioural change, reported pre- and post-relocation travel patterns were compared.

To analyse the role of residential self-selection, residents were categorised into two groups: self-selected residents and non-self-selected residents. The categorisation was based on survey responses using a set of predefined criteria. Residents were classified as non-self-selected if they met at least one of the five criteria as presented in Table 3. The first and strongest indicator of non-self-selection was residents who explicitly stated they moved to Cartesius out of necessity, due to limited housing options or housing shortages. The remaining four criteria reflect residential dissonance among residents. The rationale for each indicator is also provided in Table 3.

| Indicator | Criterion | Reason |
|---|---|---|
| Reason for moving to Cartesius | 'Other' - only available option, no choice, housing shortage, waiting list rental apartment, . . . | The person did not actively choose this neighbourhood based on its mobility concept but rather moved due to external constraints |
| Preference living scenario | Traditional, car parked in front of house as #1 | Indicates a preference for a more car-oriented living environment, which is misaligned with the low-car concept of Cartesius |
| Mode preference | Car as #1 | Suggests a strong preference for car use, which conflicts with the intended mobility concept that prioritises other modes |
| Modal split - car use | Car use 5 times a week or more | Reflects a high dependency on car travel, contradicting the neighbourhood's aim to promote alternative transport modes |
| Car ownership | 2 or more cars in household | Suggests a reliance on private vehicles, which is inconsistent with the car-reducing ambitions of the area |

**Table 3. Criteria used for assigning people to group of non self-selected residents**

The survey results were analysed to identify differences between self-selected and non-self-selected residents in terms of mobility adaptation and satisfaction levels. This classification allowed for an analysis of how self-selection influences travel behaviour and attitudes towards the low-car concept. Cross-tabulation and chi-square tests ($p < 0.05$) were used to identify statistically significant differences between the two resident groups. By comparing the two groups, the study investigates whether non-self-selected residents also adapt their mobility behaviour in response to the built environment, providing insights into the effectiveness of low-car policies beyond pre-existing preferences.

## III. Results

### A. Changes in mobility behaviour

The results show that, since moving to Cartesius, residents' overall travel behaviour has shifted toward more sustainable modes. The key figures reflecting this shift are listed in Table 4. Public transport use and shared car adoption increased, while car use and ownership declined. Specifically, 20% of previous car owners disposed of their vehicle, and an additional 13% were considering doing so. Every respondent who got rid of their car mentioned the limited parking spaces as the primary reason, highlighting the effectiveness of parking policies in reducing car ownership (Figure 2). Active modes play a dominant role across various trip purposes, replacing car and public transport trips. However, it is important to note that for the majority of residents, no significant changes in travel behaviour have been observed. This is evident in Figure 1, which presents the modal split before and after relocation, showing only minor differences. This stability can be partly explained by the already low levels of car ownership and use prior to relocation, indicating that the observed behavioural changes are most pronounced among those who previously used cars more frequently.

| | |
|---|---|
| Percentage of people using more public transport | 30% |
| Percentage of people using shared cars more often | 27% |
| Percentage of people who have reduced car use | 28% |

**Table 4. Changes in travel behaviour after residential relocation**

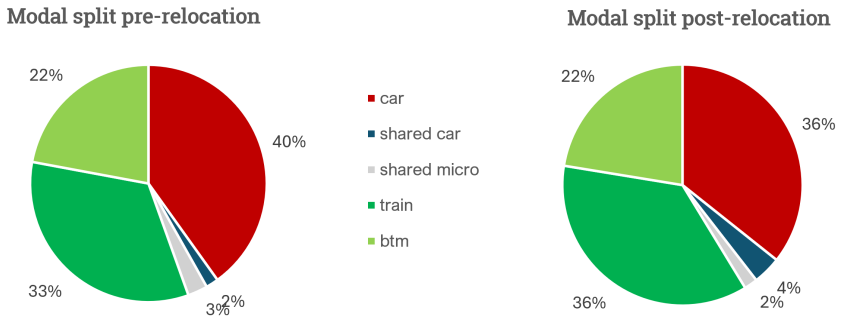


**Figure 1. Modal split before and after relocation - excluding active modes**

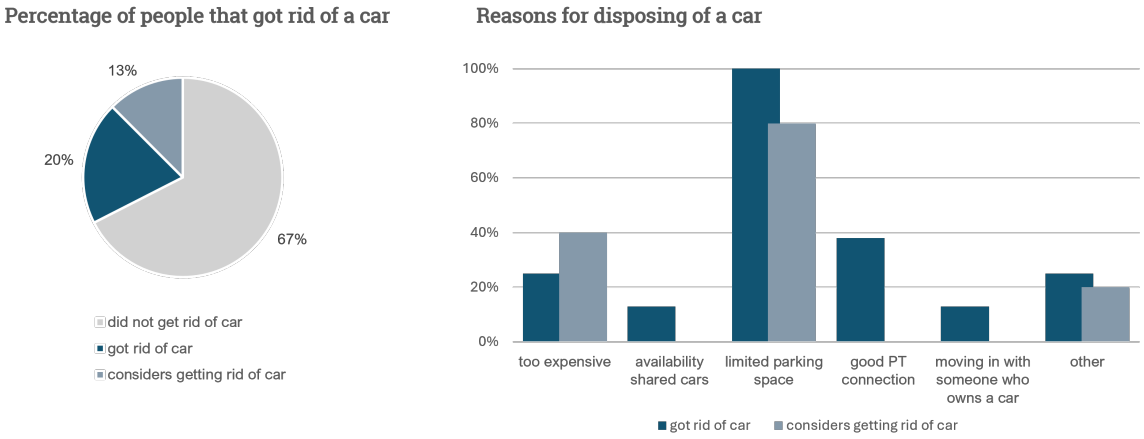


**Figure 2. Decrease in car ownership**

## B. Perception of measures

The findings reveal a generally rather negative perception of the neighbourhood's mobility options, revealing widespread dissatisfaction. Figure 3 shows that more than half of the residents feel their mobility needs are not sufficiently met, while Figure 4 provides an overview of residents' satisfaction levels with different mobility aspects of the neighbourhood.

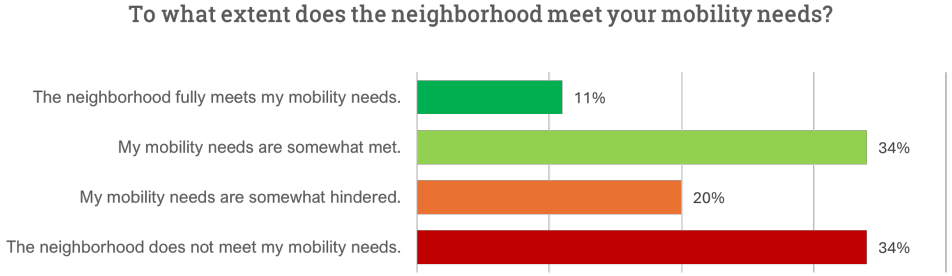


**Figure 3. Survey responses regarding mobility needs**

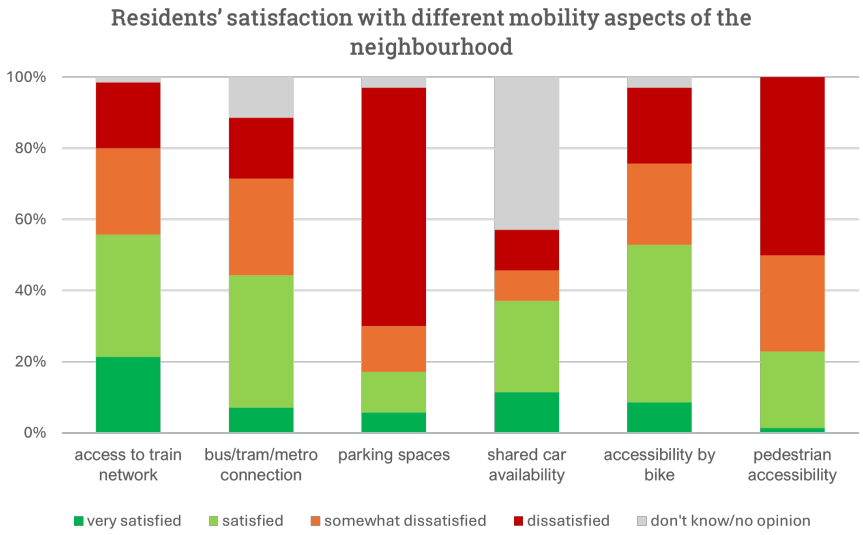


**Figure 4. Residents' perception of the neighbourhood's mobility aspects**

As can be seen from Figure 4, pedestrian accessibility and car parking receive the most negative ratings. From the conversations with residents it becomes even more clear that people are unhappy about the parking situation. It is a well bespoken topic and people, either car owners or not, have something to complain about. Residents also feel like they were not well informed before moving, with 30% of residents stating they felt incorrectly or insufficiently informed about the neighbourhoods parking policy before moving in. Communication via the municipality or developers is perceived as poorly. Positive experiences are mentioned in relation to the free trip minutes provided for shared car use. More than one-third of residents have made use of this incentive, and many indicated that it encouraged them to use shared cars more frequently.

### C. Role of residential self-selection

Based on the criteria mentioned in Table 3 a significant portion (57%) of residents in Cartesius fell into the non-self-selected category. Many respondents (N=18) explicitly stated they had no other housing options due to the housing shortage, with comments such as: *"It was the only apartment I was assigned, if you decline, you're waiting another year."* Others were identified as non-self-selected based on survey responses which revealed that their mobility patterns did not align with the neighbourhood's low-car concept. This revealed that many residents showed signs of residential dissonance. With 31% of respondents saying they would prefer to live in a traditional neighbourhood with cars parked in front of houses in the public space, 26% of people ranking the car as their favourite mode, 26% using the car five times a week or more, and two respondents indicating they own two or more cars.

The survey responses of both groups are compared and presented in Table 5. Key findings are discussed below.

| | Self-selected residents (N=30) | Non self-selected residents (N=40) | Significance |
|---|---|---|---|
| **Mobility behaviour adaption after relocation** | | | |
| Percentage of car owners that have gotten rid of car or are considering it | 50% | 28% | ns |
| Percentage of people using more PT since moving | 23% | 35% | ns |
| Percentage of people using shared cars more often | 40% | 18% | p = 0,036 |
| Percentage of people who have reduced car use | 45% | 22% | ns |
| **Perception of neighbourhood's low-car concept and sustainable mobility measures** | | | |
| Percentage of people that is (really) content with living in Cartesius | 83% | 78% | ns |
| Percentage of people that say the neighbourhood meets their mobility needs | 53% | 40% | ns |
| Satisfaction with parking spaces, accessibility by foot, accessibility cycling, availability of shared cars, access to train network | No difference | | |
| Satisfaction with connection to bus/tram/metro | More satisfied | More dissatisfied | p = 0,022 |
| Percentage of people that feel well-informed about parking policy | 70% | 55% | p = 0,035 |
| **Socio-demographic characteristics** | | | |
| Percentage of car-free households | 80% car-free | 30% car-free | p < 0,001 |
| Socio-demographics (education level, age, gender, household composition) | No difference | | |
| Previous residential area | No difference | | |

**Table 5. Comparison of groups of self-selected and non self-selected residents**

The results indicate that residents from both groups adapt their behaviour in line with the goals of reducing car dependency. In both groups, there are signs of lower car use, lower car ownership, and increased use of alternative modes of transport. The use of shared cars has increased across the board, but self-selected residents have adopted this mode significantly more often.

By definition, car ownership is significantly lower among self-selected residents, with a much higher share of car-free households in this group. There is no significant difference, however, in the percentage of people who have gotten rid of a car or are considering doing so. The 28% of non-self-selected residents considering car disposal is quite high, indicating that this group also shows signs of adapting their mobility behaviour. When looking at changes in public transport use, the self-selected group shows little increase. This can be explained by the fact that almost all of these residents were already frequent public transport users, leaving limited room for further growth. In contrast, the non-self-selected group demonstrates behavioural change, with more than one-third of these residents reporting increased public transport use since moving to Cartesius.

Self-selected residents were significantly more likely to feel well-informed about the parking policy than non-self-selected residents. Satisfaction levels were similarly low across both groups, particularly concerning different mobility aspects. Which is a very unexpected finding - that self-selected and non-self-selected are both as (un)happy.

When looking at factors influencing the residential move, no significant differences are found between the

groups. Even the importance attributed to the car-free public space does not differ significantly - as this was only reported to be important for very few people, so it is about small numbers. Proximity to public transport emerges as an important factor for both groups. Notably, car owners also indicate that proximity to public transport influenced their choice.

No socio-demographic differences were found between the groups, largely due to the homogeneous population living in Cartesius. The study also found no differences based on previous residential location, suggesting that mobility adaptation in the neighbourhood was not directly linked to where people had lived before.

## IV. Discussion

The main limitations of this study are the small target group and its specific characteristics. Focusing on this single case allowed for a more in-depth understanding of the local context through case visits and informal conversations with residents, essentially 'becoming one with the case'. However, this also means the findings are highly specific to this unique setting and cannot be easily generalised. While Cartesius can be seen as an example of the growing number of high-density, low-car, inner-city residential projects emerging in many cities, it does not serve as an empirically representative sample of such developments. The neighbourhood hosts a relatively homogeneous and specific group of residents, making it difficult to extrapolate findings to the general population. Residents of Cartesius share characteristics typically associated with low-car households, which might lead to an overestimation of the positive perceptions of the mobility concept. Though the presence of a significant number of non-self-selected residents contradicts this.

Additionally, the neighbourhood is still under development, which introduces strong contextual influences. The current living situation differs from what was initially planned, and many public spaces and mobility features are not yet completed. Furthermore, residents have only lived in Cartesius for a relatively short time, meaning the observed behavioural patterns are still evolving. The study, therefore, provides early insights into the effects of the low-car policy, but the results are not yet robust enough to predict long-term outcomes or be directly applied to other contexts or the broader population.

Cartesius' demographic profile and the temporary state of development make it a less-than-perfect case, but given the limited availability of such neighbourhoods, it remains a relevant and informative study area.

Determining whether mobility changes are driven by the built environment or personal characteristics remains complex. While the study compares residents' travel behaviour before and after relocation, other factors—such as moving closer to work or life stage transitions—may also influence mobility choices. Many residents previously lived in Utrecht or other urban areas with similar accessibility levels. This suggests that many residents may not have had to significantly adapt their mobility behaviour. When the built environment or level of urbanity remains similar, there is less incentive to rethink mobility habits. Although this may reduce the extent of behavioural change, it strengthens the argument that the low-car concept itself has influenced residents' behaviour, as other environmental factors remained constant.

Two important considerations in interpreting the survey results are participation bias and the reliance on self-reported data. Residents with strong opinions, whether positive or negative, may have been more inclined to respond. The true distribution of opinions and mobility behaviours in the neighbourhood may therefore be less polarised than the results suggest. Additionally, self-reported data introduce recall bias and social desirability effects, which could influence how residents describe their mobility choices.

Finally, while this study introduces a methodology for categorising self-selected and non-self-selected residents, the distinction is not absolute. Some residents explicitly stated that they moved to Cartesius out of necessity rather than preference, making them clear cases of non-self-selection. However, the survey primarily

offered practical reasons for relocation (e.g., moving in with a partner or job relocation), which may have led to an undercount of non-self-selected residents who simply accepted an available housing option. For instance, respondents who cited reasons such as divorce or wanting a larger residence may not have actively chosen Cartesius for its low-car concept, yet were not captured as non-self-selected in the strictest sense. This suggests that the actual number of residents who ended up in Cartesius without a deliberate preference for its mobility concept might be higher than the survey results indicate.

Moreover, while individuals in the non-self-selected category displayed some degree of misalignment with Cartesius' low-car concept, it cannot be determined with certainty whether they did not self-select to some extent. Residents' current misalignment might be a reflection of the neighbourhood not yet fulfilling its intended vision, rather than a fundamental rejection of its low-car concept. Similarly, the classification of self-selected residents should also be interpreted with caution. This group was defined by the absence of non-self-selection indicators rather than an explicit, proactive choice for a low-car lifestyle, making it a residual category rather than a definitive assessment of preference.

Despite these nuances, the distinction between self-selected and non-self-selected residents remains valuable. It provides insights into the role of residential self-selection in mobility adaptation and highlights how even non-self-selected residents adjust their behaviour in response to a low-car environment.

## V. Conclusion

This study contributes to the understanding of low-car neighbourhoods by examining the role of residential self-selection and its influence on mobility adaptation. By using a revealed preference approach, this research provides empirical evidence on how both self-selected and non-self-selected residents adjust their mobility behaviour when moving to a low-car neighbourhood. The high proportion (57%) of non-self-selected residents in Cartesius challenges the assumption that people in low-car neighbourhoods always actively choose this lifestyle. This suggests a broader trend, with more non-self-selected residents likely to move into low-car areas in the future. The findings demonstrate that even residents who did not actively choose a low-car environment reduce car ownership and usage while increasing public transport and shared car use. This suggests that well-designed low-car policies can influence travel behaviour beyond pre-existing preferences, supporting their viability as a strategy for managing urban space and promoting sustainable mobility.

The findings of this study have important implications for the future development of low-car residential areas. First, the results confirm that low-car neighbourhoods can be effective in reducing car dependency, as demonstrated by the observed decline in car ownership and usage. With 33% of (former) car owners disposing of a car or seriously considering doing so, and 28% of surveyed residents driving less frequently. Second, the study shows that the concept can trigger change in mobility behaviour for both self-selected and non-self-selected residents, meaning that large-scale low-car policies could be viable for a broader population beyond those who actively choose this lifestyle. This challenges the assumption that low-car neighbourhoods only succeed when residents are already inclined toward sustainable mobility.

Furthermore, in the case of Cartesius, the negative perceptions reported by residents can largely be attributed to contextual factors. Dissatisfaction was not confined to non-self-selected residents, indicating that negative perceptions were more related to implementation challenges than to the low-car concept itself. Issues such as incomplete infrastructure, temporary parking arrangements, and inadequate communication about mobility policies contributed to dissatisfaction. These findings confirm that the success of low-car developments depends not only on their design but also on careful implementation and management. The importance of ensuring that the necessary infrastructure, such as pedestrian and cycling facilities, is in place from the outset to prevent frustration. Additionally, clear and transparent communication with residents about mobility policies, particularly parking regulations, is essential to set realistic expectations and avoid

misunderstandings.

Overall, this is promising news for the future of large-scale low-car developments. Despite possible dissatisfaction from the residents, low-car neighbourhoods can be effective in altering individual travel behaviour in a desired way, which is the central planning goal. If well-executed, these neighbourhoods have the potential to support sustainable mobility even among those who did not initially choose a car-free lifestyle.

Future research should build on these findings by conducting longitudinal studies to assess long-term behavioural adaptation and policy effectiveness over time. Additionally, research should expand to include a more diverse population, as the residents of Cartesius, while offering a valuable first step beyond traditionally self-selected low-car communities, still represent a relatively homogeneous group. Understanding how low-car policies affect a broader demographic will be key to scaling up these developments successfully. As cities continue to implement such developments, it is crucial to investigate whether these neighbourhoods can still have the intended effects on the broader population and whether this group is also able to adapt their mobility patterns. In this context, it will be particularly important to measure accessibility in future studies to ensure these neighbourhoods do not create fundamental mobility problems.

Additionally, future studies should continue refining approaches to measuring self-selection, potentially through alternative grouping techniques or more advanced statistical models. A more precise understanding of self-selection effects would contribute to more accurate assessments of the causal relationships between the built environment and mobility behaviour, particularly in the unique context of low-car neighbourhoods. Understanding the role of residential self-selection remains a key factor in interpreting the success of these neighbourhoods.

## References


[1] UnitedNations, "— SDG indicators," 2023. URL https://unstats.un.org/sdgs/report/2023/goal-11/.

[2] voor Mobiliteitsbeleid, K., "De maatschappelijke effecten van het wijdverbreide autobezit in Nederland." , 2 2022.

[3] Creutzig, F., Javaid, A., Soomauroo, Z., Lohrey, S., Milojevic-Dupont, N., Ramakrishnan, A., Sethi, M., Liu, L., Niamir, L., Bren d'Amour, C., et al., "Fair street space allocation: ethical principles and empirical insights," *Transport Reviews*, Vol. 40, No. 6, 2020, pp. 711–733.

[4] Zijlstra, T., Witte, J., and Bakker, S., "Verklaringen voor de verschillen in autobezit bij Nederlandse huishoudens." , 2 2022.

[5] Banister, D., "The sustainable mobility paradigm," *Transport policy*, Vol. 15, No. 2, 2008, pp. 73–80.

[6] EEA, "The first and last mile—the key to sustainable urban transport," , 2020.

[7] Seto, K. C., Güneralp, B., and Hutyra, L. R., "Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools," *Proceedings of the National Academy of Sciences*, Vol. 109, No. 40, 2012, pp. 16083–16088.

[8] Newman, P., and Kenworthy, J., *Sustainability and cities: overcoming automobile dependence*, Island Press, 1998.

[9] Gehl, J., *Cities for people*, Island press, 2013.

[10] Nieuwenhuijsen, M., Bastiaanssen, J., Sersli, S., Waygood, E. O. D., and Khreis, H., *Implementing Car-Free Cities: Rationale, Requirements, Barriers and Facilitators*, Springer International Publishing, Cham, 2019, pp. 199–219. doi: 10.1007/978-3-319-74983-9$_1$1, *URL*.

Urry, J., The 'system'of automobility, *Theory, culture & society*, Vol. 21, No. 4-5, 2004, pp. 25–39.

Manderscheid, K., Formierung und Wandel hegemonialer Mobilitätsdispositive: automobile Subjekte und urbane Nomaden, 2014.

Jones, P., The evolution of urban mobility: The interplay of academic and policy perspectives, *IATSS research*, Vol. 38, No. 1, 2014, pp. 7–13.

Selzer, S., Car-reduced neighborhoods as blueprints for the transition toward an environmentally friendly

urban transport system? A comparison of narratives and mobility-related practices in two case studies, *Journal of Transport Geography*, Vol. 96, 2021, p. 103126. https://doi.org/10.1016/j.jtrangeo.2021.103126, https://www.sciencedirect.com/science/article/pii/S0966692321001794.

Borges, B. F. D. S., and Goldner, L. G., Implementation of car-free neighbourhoods in medium-sized cities in Brazil, a case study in Florianópolis, Santa Catarina, *International Journal of Urban Sustainable Development*, Vol. 7, No. 2, 2015, pp. 183–195.

Müller, M., and Reutter, P. O., Course change: Navigating urban passenger transport toward sustainability through modal shift, *International Journal of Sustainable Transportation*, Vol. 16, No. 8, 2022, pp. 719–743.

Crawford, J. H., *Carfree cities*, 2000.

Melia, S., Parkhurst, G., and Barton, H., Carfree, Low-car–What's the Difference? *World Transport Policy & Practice*, Vol. 16, No. 2, 2010.

Borgers, A., Snellen, D., Poelman, J., and Timmermans, H., Preferences for car-restrained residential areas, *Journal of Urban Design*, Vol. 13, No. 2, 2008, pp. 257–267.

Kuss, P., and Nicholas, K. A., A dozen effective interventions to reduce car use in European cities: Lessons learned from a meta-analysis and transition management, *Case studies on transport policy*, Vol. 10, No. 3, 2022, pp. 1494–1513.

Baehler, D., and Rérat, P., Beyond the car. Car-free housing as a laboratory to overcome the "system of automobility", *Applied mobilities*, Vol. 7, No. 3, 2022, pp. 280–297.

Sprei, F., Hult, C., Hult, Å., and Roth, A., Review of the effects of developments with low parking requirements, *Sustainability*, Vol. 12, No. 5, 2020, p. 1744.

Selzer, S., and Lanzendorf, M., Car independence in an automobile society? The everyday mobility practices of residents in a car-reduced housing development, *Travel behaviour and society*, Vol. 28, 2022, pp. 90–105.

Marsden, G., The evidence base for parking policies—a review, *Transport policy*, Vol. 13, No. 6, 2006, pp. 447–457.

Dijk, M., Givoni, M., and Diederiks, K., Piling up or packaging policies? An ex-post analysis of modal shift in four cities, *Energies*, Vol. 11, No. 6, 2018, p. 1400.

De Vos, J., Ettema, D., and Witlox, F., Changing travel behaviour and attitudes following a residential relocation, *Journal of Transport Geography*, Vol. 73, 2018, pp. 131–147.

Schwanen, T., and Mokhtarian, P. L., What affects commute mode choice: neighborhood physical structure or preferences toward neighborhoods? *Journal of transport geography*, Vol. 13, No. 1, 2005, pp. 83–99.

Handy, S., Cao, X., and Mokhtarian, P., Correlation or causality between the built environment and travel behavior? Evidence from Northern California, *Transportation Research Part D: Transport and Environment*, Vol. 10, No. 6, 2005, pp. 427–444.

Cao, X., Mokhtarian, P. L., and Handy, S. L., Examining the impacts of residential self-selection on travel behaviour: a focus on empirical findings, *Transport reviews*, Vol. 29, No. 3, 2009, pp. 359–395.

Naess, P., Tempest in a teapot: The exaggerated problem of transport-related residential self-selection as a source of error in empirical studies, *Journal of transport and land use*, Vol. 7, No. 3, 2014, pp. 57–79.

Ewing, R., and Cervero, R., Travel and the built environment: A meta-analysis, *Journal of the American planning association*, Vol. 76, No. 3, 2010, pp. 265–294.

# B

# Survey

# Cartesius

Start van blok: Consent

consent Welkom! Bedankt voor uw interesse in deze enquête. Dit onderzoek richt zich op de ervaringen van bewoners in autoluwe wijken en wordt uitgevoerd door Femke Mureau, masterstudent aan de TU Delft, in samenwerking met de gemeente Utrecht. De enquête duurt ongeveer 10 minuten en bevat vragen over uw vervoerskeuzes en ervaringen in uw buurt. Uw antwoorden worden anoniem verwerkt en gebruikt voor mijn afstudeeronderzoek. Om uw privacy te beschermen, slaan we geen IP-adressen of andere direct identificeerbare gegevens op. Omdat we enkele algemene gegevens vragen, zoals leeftijd en huishoudsamenstelling, kan volledige anonimiteit echter niet altijd worden gegarandeerd. Deelname is geheel vrijwillig. U kunt op elk moment stoppen of vragen overslaan. Omdat de enquête geen persoonsgegevens opslaat, kunnen uw antwoorden niet worden verwijderd nadat u ze heeft ingediend. Heeft u vragen? Neem dan contact op via f.w.b.mureau@student.tudelft.nl. Door verder te gaan, geeft u aan dat u deze informatie hebt gelezen en akkoord gaat met deelname aan dit onderzoek.

Einde blok: Consent

Start van blok: Main survey

rijbewijs Heeft u of iemand in uw huishouden een rijbewijs?

- ○ ja (1)
- ○ nee (2)

autobezit Over hoeveel (lease) auto's beschikt uw huishouden?

- ○ geen (1)
- ○ 1 (2)
- ○ 2 (3)
- ○ 3 or meer (4)

deelvervoer Van welke vormen van deelvervoer heeft u of iemand in uw huishouden in de afgelopen 12 maanden gebruik gemaakt? U mag meer antwoorden aankruisen

- [ ] elektrische deelfiets (zoals Tier) (1)
- [ ] elektrische bakfiets (zoals Cargoroo) (2)
- [ ] OV-fiets (3)
- [ ] deelauto via een commerciële organisatie (zoals Greenwheels) (4)
- [ ] deelauto via een website met bewonersaanbod (zoals SnappCar) (5)
- [ ] auto van familie, vrienden, kennissen of buren (6)
- [ ] geen van bovenstaande (7)

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tekst Het volgende deel gaat over hoe uw reisgedrag eventueel is veranderd na uw verhuizing naar Cartesius.

modal split 1 Sinds uw verhuizing naar Cartesius, hoe vaak per week maakt u gebruik van de volgende modaliteiten?

| | 5 keer of meer per week (1) | 3-4 keer per week (2) | 1-2 keer per week (3) | 1-3 keer per maand (4) | minder dan 1 keer per maand (5) | nooit (6) |
|---|---|---|---|---|---|---|
| privé auto (ook lease) (1) | ○ | ○ | ○ | ○ | ○ | ○ |
| deelauto (of geleende auto) (2) | ○ | ○ | ○ | ○ | ○ | ○ |
| deelscooter, deel(bak)fiets, deelstep (3) | ○ | ○ | ○ | ○ | ○ | ○ |
| trein (4) | ○ | ○ | ○ | ○ | ○ | ○ |
| bus, tram en/of metro (5) | ○ | ○ | ○ | ○ | ○ | ○ |

modal split 2 Welk vervoermiddel (of een combinatie daarvan) gebruikt u per doeleinde? U mag meer antwoorden aankruisen

| | privé auto (ook lease) (1) | deelauto (2) | trein (3) | bus/ tram/ metro (4) | motor/ scooter/ brommer (5) | deelscooter, deel(bak)fiets, deelstep (6) | fiets (of e-bike) (7) | lopend (8) | n.v.t. (9) |
|---|---|---|---|---|---|---|---|---|---|
| werk/school (1) | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| kinderen naar school/sport/activiteiten brengen (2) | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| boodschappen/winkelen (3) | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| vrijetijdsbesteding alleen, zonder huishouden, zoals uit eten of sport (4) | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| vrijetijdsbesteding samen met het huishouden (5) | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

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modal split 3 We vragen u even terug te denken aan uw vorige woonplek. Voor uw verhuizing naar Cartesius, hoe vaak per week maakte u gebruik van de volgende modaliteiten?

| | 5 keer of meer per week (1) | 3-4 keer per week (2) | 1-2 keer per week (3) | 1-3 keer per maand (4) | minder dan 1 keer per maand (5) | nooit (6) |
|---|---|---|---|---|---|---|
| privé auto (ook lease) (1) | ○ | ○ | ○ | ○ | ○ | ○ |
| deelauto (of geleende auto) (2) | ○ | ○ | ○ | ○ | ○ | ○ |
| deelscooter, deel(bak)fiets, deelstep (3) | ○ | ○ | ○ | ○ | ○ | ○ |
| trein (4) | ○ | ○ | ○ | ○ | ○ | ○ |
| bus, tram en/of metro (5) | ○ | ○ | ○ | ○ | ○ | ○ |

modal split 4 Welk vervoermiddel (of een combinatie daarvan) gebruikte u toen per doeleinde? U mag meer antwoorden aankruisen

| | privé auto (ook lease) (1) | deelauto (2) | trein (3) | bus/ tram/ metro (4) | motor/ scooter/ brommer (5) | deelscooter, deel(bak)fiets, deelstep (6) | fiets (of e-bike) (7) | lopend (8) | n.v.t. (9) |
|---|---|---|---|---|---|---|---|---|---|
| werk/school (1) | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| kinderen naar school/sport/activiteiten brengen (2) | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| boodschappen/winkelen (3) | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| vrijetijdsbesteding alleen, zonder huishouden, zoals uit eten of sport (4) | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| vrijetijdsbesteding samen met het huishouden (5) | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

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auto weggedaan Heeft u of uw huishouden een auto weggedaan sinds uw verhuizing naar Cartesius?

- ja, ik heb een (of meerdere) auto's weggedaan (1)
- nee, maar ik overweeg wel om een (of meerdere) auto's weg te doen (2)
- nee, ik heb geen auto('s) weggedaan (3)

*Deze vraag weergeven:*

*If Heeft u of uw huishouden een auto weggedaan sinds uw verhuizing naar Cartesius? = ja, ik heb een (of meerdere) auto's weggedaan*

ja auto weggedaan Als u een auto heeft weggedaan sinds uw verhuizing naar Cartesius, welke stellingen zijn dan op u van toepassing? U mag meer antwoorden aankruisen

- ☐ ik heb een auto weggedaan omdat het te duur was (1)
- ☐ ik heb een auto weggedaan omdat deelauto’s beschikbaar zijn in de wijk (2)
- ☐ ik heb een auto weggedaan omdat er niet genoeg parkeerplekken zijn in de wijk (3)
- ☐ ik heb een auto weggedaan omdat de aansluiting met het openbaar vervoer in de wijk goed is (4)
- ☐ ik heb een auto weggedaan omdat ik samen ben gaan wonen met iemand die een auto heeft (5)
- ☐ anders, namelijk: (6) _____

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*Deze vraag weergeven:*

*If Heeft u of uw huishouden een auto weggedaan sinds uw verhuizing naar Cartesius? = nee, maar ik overweeg wel om een (of meerdere) auto's weg te doen*

overweeg auto weg Als u sinds uw verhuizing naar Cartesius overweegt om een auto weg te doen, welke stellingen zijn dan op u van toepassing? U mag meer antwoorden aankruisen

- ☐ ik overweeg een auto weg te doen omdat het te duur is (1)
- ☐ ik overweeg een auto weg te doen omdat deelauto's beschikbaar zijn in de wijk (2)
- ☐ ik overweeg een auto weg te doen omdat er niet genoeg parkeerplaatsen zijn in de wijk (3)
- ☐ ik overweeg een auto weg te doen omdat de aansluiting met het openbaar vervoer in de wijk goed is (4)
- ☐ ik overweeg een auto weg te doen omdat ik samen ben gaan wonen met iemand die een auto heeft (5)
- ☐ anders, namelijk: (6) _____

Pagina-einde

reden verhuizen Wat was de  reden voor uw verhuizing naar Cartesius? U mag meer antwoorden aankruisen.

- [ ] ik wilde/wij wilden groter wonen  (1)
- [ ] ik wilde/wij wilden kleiner wonen  (2)
- [ ] samenwonen/trouwen  (9)
- [ ] (planning) geboorte kind  (11)
- [ ] scheiding  (10)
- [ ] verandering baan (of verandering baan partner)  (5)
- [ ] omgeving paste niet meer bij mij/ons  (6)
- [ ] aantrekkelijkere woning  (8)
- [ ] anders, namelijk  (12) _____

stedelijkheid Voor uw verhuizing, wat was de mate van stedelijkheid waarin u woonde?

- ○ in het stadscentrum van Utrecht  (1)
- ○ tussen stadscentrum en stadsrand binnen Utrecht  (2)
- ○ in het stadscentrum van een andere stad  (3)
- ○ tussen stadscentrum en stadsrand in een andere stad  (4)
- ○ in de bebouwde kom van een kleinere gemeente (of dorp)  (5)
- ○ buiten de bebouwde kom  (6)

belangrijk verhuizen Hoe belangrijk waren de volgende redenen om in Cartesius te komen wonen?

| | heel belangrijk (1) | belangrijk (2) | enigszins belangrijk (3) | niet belangrijk (4) | dit was geen reden voor mij (5) |
|---|---|---|---|---|---|
| nabijheid van werk (1) | ○ | ○ | ○ | ○ | ○ |
| nabijheid van juiste basis- of middelbare school (2) | ○ | ○ | ○ | ○ | ○ |
| nabijheid van OV (3) | ○ | ○ | ○ | ○ | ○ |
| beschikbaarheid van deelauto's (4) | ○ | ○ | ○ | ○ | ○ |
| energielabel woning (5) | ○ | ○ | ○ | ○ | ○ |
| prijs van de woning (6) | ○ | ○ | ○ | ○ | ○ |
| de visie van de wijk met een focus op gezond stedelijk leven (7) | ○ | ○ | ○ | ○ | ○ |
| de autovrije openbare ruimtes die ontwikkeld gaan worden (8) | ○ | ○ | ○ | ○ | ○ |

tevredenheid buurt Wat vindt u van wonen in Cartesius?

- ○ zeer prettig (1)
- ○ prettig (2)
- ○ onprettig (3)
- ○ zeer onprettig (4)
- ○ weet ik niet/geen mening (5)

---

tevreden mobiliteit In hoeverre bent u tevreden over de volgende aspecten in de wijk Cartesius?

| | zeer tevreden (1) | tevreden (2) | enigszins ontevreden (3) | ontevreden (4) | weet ik niet/geen mening (5) |
|---|---|---|---|---|---|
| aansluiting op treinnetwerk (1) | ○ | ○ | ○ | ○ | ○ |
| bus/tram/metro verbinding (2) | ○ | ○ | ○ | ○ | ○ |
| autoparkeerplaatsen (3) | ○ | ○ | ○ | ○ | ○ |
| aanbod van deelauto's (4) | ○ | ○ | ○ | ○ | ○ |
| bereikbaarheid met de fiets (5) | ○ | ○ | ○ | ○ | ○ |
| bereikbaarheid lopend (6) | ○ | ○ | ○ | ○ | ○ |
| aanbod van gedeelde e-bikes, fietsen en bakfietsen (7) | ○ | ○ | ○ | ○ | ○ |
| fietsparkeerplaatsen (8) | ○ | ○ | ○ | ○ | ○ |

---

gratis rijminuten Bij uw verhuizing naar Cartesius heeft u een aanbod gekregen voor gratis rijminuten voor de deelauto's van We Drive Solar (inmiddels overgenomen door MyWheels). Welke stelling past bij u? U mag meer antwoorden aankruisen

- [ ] ik heb gebruikt gemaakt van de gratis rijminuten (1)
- [ ] ik ben niet bekend met de gratis rijminuten (2)
- [ ] ik maakte al gebruik van deelauto's (3)
- [ ] ik ben na het aanbod van gratis rijminuten vaker gebruik gaan maken van deelauto's (4)
- [ ] ik heb geen gebruik gemaakt van de gratis rijminuten (5)
- [ ] anders, namelijk: (6) _____

---

parkeerbeleid Bent u voor uw verhuizing voldoende geïnformeerd over het parkeerbeleid in de wijk?

- ○ ja, ik heb het gevoel voldoende geïnformeerd te zijn (1)
- ○ nee, ik heb onjuiste informatie gekregen/gevonden (2)
- ○ nee, ik heb geen of te weinig informatie gekregen/gevonden (3)
- ○ weet ik niet/geen mening (4)

---

mobiliteitsbehoefte In hoeverre sluit de wijk aan bij uw mobiliteitsbehoefte (denk bijvoorbeeld aan: parkeerdruk, ov-bereikbaarheid, reisduur, toegang tot gewenste mobiliteitsopties, etc.)

- ○ de wijk voldoet volledig aan mijn mobiliteitsbehoeften (1)
- ○ er wordt enigszins aan mijn mobiliteitsbehoeften voldaan (2)
- ○ mijn mobiliteitsbehoeften worden enigszins belemmerd (3)
- ○ de wijk voldoet niet aan mijn mobiliteitsbehoeften (4)

---

stedelijk voorkeur Wat voor mate van stedelijkheid heeft uw voorkeur?

- ○ ik woon liever in een buitenwijk met meer ruimte (1)
- ○ ik woon liever in een hoog stedelijke wijk met meer voorzieningen (2)

---

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vervoermiddel Met welk vervoermiddel verplaatst u zich het liefst (even afgezien van de afstand) en welke vervoermiddelen komen op de tweede, derde, vierde en vijfde plaats?
_____ auto (1)
_____ trein (2)
_____ bus/tram/metro (3)
_____ fiets (4)
_____ lopend (5)

Pagina-einde

woon-scenario Aan welk woon-scenario geeft u de voorkeur? Rangschik de opties zoals op u van toepassing

_____ Auto voor de deur: een traditionele woonwijk met ruimte voor auto’s in de openbare ruimte (1)

_____ Autovrij concept: een wijk met meer groene openbare voorzieningen en ruimte voor speeltuinen. Geen auto’s in de openbare ruimte, maar voldoende parkeerplekken aan de rand van de wijk (2)

_____ Autoluw concept: een wijk met meer groene openbare voorzieningen en ruimte voor speeltuinen. Er wordt vol ingezet op lopen, fietsen, deelauto’s en goed OV, maar er zijn fors minder parkeerplekken beschikbaar voor bewoners. (3)

Pagina-einde

tekst Tot slot volgen er nog een paar persoonlijke vragen, zoals over uw leeftijd, huishouden en inkomen. Deze informatie is belangrijk om uw eerdere antwoorden beter te begrijpen en te onderzoeken hoe verschillende groepen bewoners hun mobiliteit en woonomgeving ervaren.

---

gender Ik ben een:

- ○ vrouw (1)
- ○ man (2)
- ○ anders dan vrouw of man (3)
- ○ ik zeg dat liever niet (5)

---

age Hoe oud bent u?

- ○ 18 - 29 jaar (1)
- ○ 30 - 39 jaar (2)
- ○ 40 - 49 jaar (3)
- ○ 50 - 65 jaar (4)
- ○ ouder dan 65 jaar (5)

---

edu Wat is uw hoogst afgeronde opleiding?

- ○ basisonderwijs/lagere school (1)
- ○ voorbereidend middelbaar beroepsonderwijs (vmbo, lbo/vbo, mavo) (2)
- ○ middelbaar beroepsonderwijs (mbo) (3)
- ○ hoger voortgezet onderwijs (havo, vwo) (4)
- ○ hoger beroepsonderwijs (hbo) (5)
- ○ wetenschappelijk onderwijs (universiteit) (6)

---

hh comp Tot welk type huishouden behoort uw huishouden?

- ○ alleenstaand zonder thuiswonende kind/kinderen (1)
- ○ alleenstaand met thuiswonende kind/kinderen (2)
- ○ samenwonend zonder thuiswonende kind/kinderen (3)
- ○ samenwonend met thuiswonende kind/kinderen (4)
- ○ anders, namelijk: (5) _____

---

*Deze vraag weergeven:*

*If Tot welk type huishouden behoort uw huishouden? = samenwonend met thuiswonende kind/kinderen*

*Or Tot welk type huishouden behoort uw huishouden? = alleenstaand met thuiswonende kind/kinderen*

kids Tot welke leeftijdscategorie behoort uw thuiswonende kind(eren)?

- [ ] 0-6 jaar (1)
- [ ] 7-12 jaar (2)
- [ ] 13-18 jaar (3)
- [ ] ouder dan 18 jaar (4)

---

income Wat is het netto inkomen van uw huishouden per maand? (indien samenwonend, inkomens bij elkaar optellen)

- ○ minder dan 1000 euro (1)
- ○ 1000-1300 euro (2)
- ○ 1300-2600 euro (3)
- ○ 2600-4000 euro (4)
- ○ 4000-6000 euro (5)
- ○ 6000-10 000 euro (6)
- ○ meer dan 10 000 euro (7)
- ○ ik zeg dat liever niet (8)

---

Pagina-einde

sustainability Geef aan in hoeverre u het eens bent met de volgende stellingen

| | helemaal mee eens (1) | enigszins mee eens (2) | enigszins mee oneens (3) | helemaal niet mee eens (4) |
|---|---|---|---|---|
| ik vind duurzaamheid belangrijk (1) | ○ | ○ | ○ | ○ |
| ik zie mijzelf als duurzaam persoon (2) | ○ | ○ | ○ | ○ |

**Einde blok: Main survey**

**Start van blok: Submit**

tekst Dat waren alle vragen. Door op volgende te klikken, levert u de vragenlijst in.

**Einde blok: Submit**

# C

# Survey invitations

Beste bewoners van Cartesius,

Er wordt momenteel een afstudeeronderzoek uitgevoerd door Femke Mureau, student aan de Technische Universiteit Delft. Dit onderzoek richt zich op de effecten van autoluwe gebiedsontwikkeling. Om te kunnen leren van de aanpak in Cartesius, wil Femke graag weten hoe jullie de mobiliteit in en rondom de wijk ervaren.

De enquête gaat in op onderwerpen zoals de manier waarop jullie je verplaatsen (bijvoorbeeld te voet, op de fiets, met de auto of openbaar vervoer), hoe tevreden jullie zijn over de wijk, en wat jullie belangrijk vinden op het gebied van mobiliteit.

De resultaten van dit onderzoek worden gebruikt voor academische doeleinden en kunnen bijdragen aan verbeteringen in mobiliteitsoplossingen voor vergelijkbare wijken.

**De enquête invullen duurt slechts 5-10 minuten.**
Heb je even tijd om mee te doen?  Jullie mening is ontzettend waardevol en wordt zeer gewaardeerd!

Klik hier om de enquête in te vullen (vóór 20 december):
https://tudelft.fra1.qualtrics.com/jfe/form/SV_5nhH1ldGHFXnKSi

Namens Femke alvast heel erg bedankt voor jullie tijd en hulp!

Voor vragen en opmerkingen is Femke te bereiken via f.w.b.mureau@student.tudelft.nl

**Figure C.1:** Message in the Cartesius app

**Reminder: Onderzoek mobiliteit in Cartesius – vandaag of morgen nog in te vullen**

Beste medebewoners van Cartesius,

Namens Femke Mureau, student aan de Technische Universiteit Delft, stuur ik een vriendelijke herinnering voor haar enquête over de effecten van autoluwe gebiedsontwikkeling. Dit is onderdeel van haar afstudeeronderzoek.

Dank aan iedereen die de enquête al heeft ingevuld! Dat wordt ontzettend gewaardeerd. Toch zijn er nog meer reacties nodig om het onderzoek statistisch goed te kunnen onderbouwen. Heb je even tijd om mee te doen? Jullie ervaringen en inzichten zijn ontzettend belangrijk om dit onderwerp goed te onderzoeken.

De online enquête is anoniem in te vullen in zo'n 5-10 minuten en bestaat volledig uit meerkeuzevragen. Je kunt hem vandaag of morgen nog invullen via de volgende link: https://tudelft.fra1.qualtrics.com/jfe/form/SV_5nhH1ldGHFXnKSi

Namens Femke alvast heel erg bedankt!

Voor vragen en opmerkingen is Femke te bereiken via f.w.b.mureau@student.tudelft.nl

**Figure C.2:** Reminder in the Cartesius app


**Figure C.3:** Flyer with QR-code