Car-Free Residential Streets and Car Dependency

Investigating How Car-Free Residential Streets Affect Resident's Perceived Car Dependency

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PREFACE

Dear reader,

Presented here is my thesis, which I wrote to obtain my master's degree in Spatial Planning at Utrecht University. Over the past 20 weeks, I have thoroughly enjoyed conducting research on car-free streets and the concept of car dependency, which has resulted in the following product.

Throughout my four years of studying Built Environment at the University of Applied Sciences in Utrecht, I developed a strong interest in mobility and urban planning, specifically in researching and understanding behavior, perceptions, and attitudes. I was able to further develop this interest during a two-year period at Utrecht University during a pre-master's and master's program, which taught me that solutions to today's complex (urban) challenges are not immediately obvious or set in stone, that they can be approached and understood in different ways, and that they require an integral approach. I also consider the recognition of the presence of different interests, perspectives, and implications in urban projects to be very valuable and have certainly broadened my understanding of urban planning.

This master's thesis in particular has convinced me, if not actually confirmed, that throughout my professional career I want to dedicate myself every day to transforming and creating healthy, livable, safe, beautiful, and above all pleasant living environments in which people wish to reside.

Many thanks to all 81 anonymous respondents for taking the time to complete the survey. I would also like to thank my supervisor Katinka Wijsman for the helpful and constructive feedback sessions, which not only helped me in terms of substance and process, but also motivated me and boosted my confidence, both during the pre-master's and throughout this master's program.

Amersfoort, June 2025

Guus

ABSTRACT

Car-centric development has led to increasing concerns and challenges regarding livability, spatial (in)justices, and sustainability at various spatial scales, including the residential street. Developing 'car-free' has emerged as a worldwide trend to counteract car-based planning to reduce, among others, the negative effects of this dependency on cars. However, research is currently lacking on the extent to how living on a car-free street can affect residents' car dependence. Therefore, this study was conducted with the objective to explore how residents, living on a car-free residential street perceive their car dependency and to identify what role car-free residential streets play in affecting this car dependency.

The research involved a mixed methods approach consisting of a literature review and a survey with various case studies. The literature review provided the foundation for the rest of the research, in which the definition of a car-free street is established upon related literature and car dependency is divided into three levels, namely the individual (micro), circumstantial (meso) and societal (macro) level where car dependency is operationalized through an individual's subjective perception. The survey was completed by 81 respondents (n = 81) through a purposive sample, resulting in a response rate of 11%.

The study revealed the following: A car-free residential street is defined as follows: *'A residential (or mixed-use) street that does not accommodate cars and where public space is utilized for other urban features'*. Such a car-free residential street allows for a traffic-free intermediate environment providing (limited) parking separated from the street on which a residence is situated.

Looking at the composite scores for each level of car dependency, it appeared that residents on average perceive themselves to be most car independent at the macro level and most car dependent at the meso level at a scale from 1 to 5; car independent and car dependent: micro (M = 2.84, SD = 0.69), meso (M = 3.07, SD = 0.60) and macro (M = 2.42, SD = 0.71). These composite scores differed only significantly among respondents with or without a driver's license, the number of cars in the household and the type of car-free street.

Based on the Spearman rho rank correlations, it can be concluded that there is a weak to moderate positive correlation between the degree of car dependency and the influence of living on a car-free street. In addition, with the provided open answers, it can be concluded that there are differences in whether living on a car-free street contributes to residents' perceived car dependence, in which the significance differs greatly depending on the contextual and individual situation of an individual.

This research has revealed that residing on a car-free street may influence the extent to which residents consider themselves to be car-dependent. Nevertheless, this is not a primary factor, and the degree to which individuals feel dependent on cars is influenced by numerous other factors at various levels beyond the street.

However, these conclusions are only valid within this sample since these are not representative resulting in non-generalizable findings. No conclusions can be drawn about the extent to which these results are representative of other residents in car-free streets. Despite this, the study provides a useful starting point for further research into the role that living on car-free streets can play in influencing residents' dependence on cars, strengthening knowledge and understanding of car dependency in relation to car-free streets.

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1. INTRODUCTION

Cities are shaped by and centered around cars as a consequence of car-centric planning and practices as well as most residential streets which have been designed to accommodate and be dominated by traffic and parked cars (Friedman, 2020; Newman & Kenworthy, 2015; Skjœveland, 2001). This car-centric development has led to increasing concerns and challenges regarding livability, spatial (in)justices, and sustainability prompting change towards less car-centric policies (Baehler & Rérat, 2020; Bertolini, 2020; Nello-Deakin, 2019; Miner et al., 2024). While some already speak of a new era, namely the "end of automobile dependence", others are more tentative, arguing that the "system of automobility" seems to be resilient and incredibly difficult to disentangle from (Mattioli et al., 2020; Newman & Kenworthy, 2015; Baehler & Rérat, 2020).

The necessity associated with the dismantling of the ''car system'', often referred to as 'car dependency', can be justified from several prospects. For instance, many externalities detrimental to society, are associated with the car, such as air- and noise pollution, greenhouse gas emissions, congestion and road safety (Gössling, 2020; Baehler & Rérat, 2020; Saedizand et al., 2022; Miner et al., 2024; Goodwin, 1995; Nieuwenhuijsen & Khreis, 2016). Additionally, car use is associated with increased social inequalities, and it consumes valuable urban space allocated to roads and parking (Nieuwenhuijsen & Khreis, 2016; Miner et al., 2024). Such excessive consumption of land use can be contextualized as the disproportionate and uneven space allocation with regards to the car (Gössling, 2020). Specifically parking lots occupy a substantial portion of urban public space, leaving less land available for other urban functions and uses (Friedman, 2020; Kirschner & Lanzendorf, 2020; McCahill & Garrick, 2012). For instance, the average car is only in use one hour a day and is therefore parked around 95% of the time (Metz, 2023). Moreover, research shows that parking supply has an impact on decisions whether to own a car and the distance from and to a parking spot influences the choice of travel mode (Guo, 2012; Brezina & Emberger, 2017). Parking policies are therefore crucial in the management of urban space, the urban transportation system and mobility patterns and behavior of individuals and thus in reducing car dependency (Metz, 2023; Kirschner & Lanzendorf, 2020; Buehler et al., 2016).

While car dependency is embedded in our contemporary society, much effort is being put into mitigating this dependency on various spatial scales (Mattioli et al, 2020). Measures to reduce this dependency vary from facilitating safe cycling and walking infrastructure, enhancing an extensive and affordable public transportation network to taxations, fees and car-restrictive policies such as reducing speed limits and declaring areas car-free (Buehler et al., 2016). It revolves around making the car less appealing while simultaneously increasing the attractiveness of alternative modes of transportation (Metz, 2023; Vega-Gonzalo et al., 2023; M. Nieuwenhuijsen et al., 2018). Car-free areas are presumably more livable and attractive than current car-dominated cities in which inner areas of cities have the most potential demand to become car-free (M. J. Nieuwenhuijsen, 2021; Melia, 2014; Melia et al., 2012). However, regardless of the measures or policies, the essential factor is that cities must become more livable, efficient, less harmful with a more equitable use of space which could be achieved through the redistribution and reallocation of public space (ITF, 2021; Gössling, 2020).

Considering parking, it is argued that the pressure of residential parking is intensifying and posing a threat to the livability of streets (Wiersma & Bertolini, 2024). Consequently, more often municipalities consider reusing on-street parking space for other purposes to enhance livability, even though this usually results in considerable resistance among residents (Kirschner & Lanzendorf, 2020). Arguing against the car is "not done" which is an integral part of the embedded car culture (Gössling, 2020; Mattioli et al., 2020). This is evident from practical experience in Amersfoort, The Netherlands, where 76% of the residents voted against new parking policies which involves rolling out paid parking across a large part of the city to reduce the amount of privately owned cars and to keep the city livable (NOS, 2023). Finding a balance between livability and parking is therefore political and requires a more holistic approach (Wiersma & Bertolini, 2024; Antonson et al., 2017).

Despite such resistance, developing 'car-free' has emerged as a worldwide trend to counteract car-based planning and adopts different types of models and formats such as ‘car-free cities’, ‘car-free development’ and ‘car-free housing’ (Doheim et al., 2020; ITF, 2021; Morris et al., 2009; Wright, 2005; Marcheschi et al., 2022; M. J. Nieuwenhuijsen, 2021). It reflects a shift in the direction of a new mobility and planning paradigm: a new post-car system toward sustainable mobility enhancing livability, focusing on human-scale urbanism (Marcheschi et al., 2022; Baehler & Rerat, 2020; Selzer, 2021; Aumann et al., 2023). Although this transformation will not occur overnight and demands an incremental process in which standards and routines must change incrementally (Hrelja & Rye, 2022), car-free residential streets already exist in practice. However, research is currently lacking on the definition and composition of such a street, and to what extent living on a car-free street affects residents' subjective perception of their car dependence.

One study found that streetscape affects car use, but this statement is solely based on three characteristics, namely the quality of buildings, the continuity of street walls and the height-to-width ratio of a street (Liu et al., 2022), neglecting the actual layout of the street itself. Another study found that street characteristics influence car ownership and use, with human friendly streets and restricting parking reduces car dependency (Jiang et al., 2016), although it fails to discuss residential streets. At the same time, it is stated that the appearance of a streetscape is important for daily life and improving its quality is an effective strategy for improving urban health and livability (Rui & Xu, 2024; Harvey & Aultman-Hall, 2015).

Yet, previous research does not address the extent to which an individual's car dependence is affected by living on a car-free residential street or how residents living in car-free residential streets perceive their own car dependence. Knowledge about this urban form in relation to car dependency is lacking in existing theories or literature since car-free development in general remains a niche concept (Selzer & Lanzendorf, 2022). Therefore, the influence of car-free residential streets on resident’s car dependence should be explored to create a better understanding of car dependency and to investigate whether a car-free residential street plays a role in affecting car dependency. What can we learn from those who already live on such a car-free residential street where other urban features are prioritized over the car?

1.2 RESEARCH QUESTIONS

Understanding the individual dependence on the car is crucial in reducing such dependence as well as mitigating its externalities (Mattioli et al., 2016; Buehler et al., 2016; Muñoz et al., 2024; Cremer-Schulte et al., 2024; Metz, 2023). Therefore, the research objective of this study is to explore how residents, living on a car-free residential street perceive their car dependency and to identify what role car-free residential streets play in affecting this car dependency while improving the urban livability on a street. In doing so, the research is instigated from a New Urbanism perspective with emphasis on challenging the car-centric planning culture while improving the quality of life in urban areas. New Urbanism can be seen as a ‘reform movement’ which considers the physical design of public space to be a tool for enhancing the quality of life in urban areas enabling urban living, as opposed to car-dependent, land-consuming, environmentally unfriendly and badly designed public spaces (Garde, 2020; Talen, 2014; Cardoso et al., 2021). In order to achieve this research objective, the following central research question was utilized:

How does living on a car-free residential street affect residents' perceived car dependence?

The associated sub questions are given in Table 1. In this, sub question 2, 3 and 4 relate to the approach of car dependency, as identified by Mattioli et al. (2016) which will be further elaborated on in the theoretical framework.

Table 1
Associated Sub Questions

Sub question 1	How to define a car-free residential street?
Sub question 2	How do residents, living on a car-free residential street, perceive their car dependence on an individual level?
Sub question 3	How do residents, living on a car-free residential street, perceive their car dependence on a circumstantial level?
Sub question 4	How do residents, living on a car-free residential street, perceive their car dependence on a society level?
Sub question 5	To what extent do car-free residential streets play a role in residents' perceived car dependence?

1.3 SOCIETAL AND SCIENTIFIC RELEVANCE

Car dependence is a multifaceted, complex and elusive concept relevant to multiple disciplines, which requires further research in order to mitigate and reduce it (Muñoz et al., 2024; Van Eenoo, 2025). Precisely the different approaches and indicators that are being used to understand the multidimensions of car dependency emphasizes the need for a comprehensive framework to both define and operationalize it (Muñoz et al., 2024), with new research playing an invaluable role. In addition, greater knowledge regarding the concept of the car-free residential street, a topic as yet scarcely researched, may help shine more light on the multifunctional potential which can function as a foundation for subsequent research.

Urban areas must become more livable which can be achieved by the redistribution of public space, which allows for more room for humans and nature to deal with various urban sustainability challenges, through a critical approach to current mobility habits and policies (Gössling, 2020). This research can therefore contribute to strengthening knowledge of the influence of car-free residential streets on car dependency in which these insights can inform policy helping policymakers during the decision-making processes when (re)designing residential streets. All with the aim to improve and create healthy and livable urban spaces for all, specifically in residential streets while simultaneously reducing negative externalities caused by car dependency.

1.4 READING GUIDE

Now the Theoretical Framework follows in which the theoretical concepts for this study are discussed. Chapter 3 covers the Methodology, discussing the data collection and analysis, followed by the Results, in which the results for each sub-question are presented. Chapter 5 covers the Discussion, followed by the Conclusion, providing an answer to the main question. Finally, the Bibliography can be found in chapter 7 and the Appendix in chapter 8.

2. THEORETICAL FRAMEWORK

The theoretical framework provides an elaboration of the fundamental concepts used in this study drawing on existing literature. In this regard, first the car-free street will be discussed, after to which the concept of car dependency is outlined.

2.1 CAR-FREE RESIDENTIAL STREET

There is no definition of a 'car-free residential street' to be found in literature, despite numerous notions including 'car-free', 'car-lite', 'car-low', 'car restricted', 'car reduced', 'car independent', 'car restrained' and 'car limited' (Wright, 2005; Morris et al., 2009; Melia, 2014; Aumann et al., 2023; Miner et al., 2024; Doheim et al., 2020; Selzer, 2021; Borges et al., 2008). These can furthermore be applied to different spatial scales such as neighborhoods, areas, zones, districts and cities (Wright, 2005; Miner et al., 2024; ITF, 2021; Aumann et al., 2023; Nieuwenhuijsen, 2021; Gundlach et al., 2018; Topp & Pharoah, 1994; Selzer, 2021; Nieuwenhuijsen & Khreis, 2016).

Yet, there is no definition of a 'car-free residential street'. According to Wright (2005), a 'car-free street' functions as a permanent local measure, however, he fails to elaborate on forms and types of permanent car-free streets. Nevertheless, there are definitions of 'car-free development' relating to housing. 'Car-free' in general relates to sites where there is no access or parking available for motorized vehicles, but there are differences (Morris et al., 2009):

(I) A 'visually car-free' residential area does not include parking and motorized access, since it is designed for pedestrian access and cyclist and to provide for more green public spaces. However, this does not necessarily restrict car ownership since parking is often available in (underground) parking garages, at the edge of the neighborhood or on private property.
(II) 'Low car/reduced' residential development is distinctive for overall reduced parking standards, often in combination with a limited amount of parking permits or a controlled parking zone.
(III) Within 'Car-free' housing development, no provision has been made for car infrastructure and on-site parking. Optional parking is provided but at high charges and located outside the neighborhood and therefore function often on a neighborhood scale.

In addition, according to Melia et al (2011), 'car-free' developments are residential or mixed-use developments that (I) typically accommodate a traffic-free immediate environment, (II) provide no or limited parking separate from the residence, and (III) have been designed to allow residents to live car-free. Despite the fact that there is no universal definition of car-free residential developments either, it can provide the foundation for defining a 'car-free residential street'. First, however, the definition of a residential street in general must be specified.

2.1.1 CHARACTERISTICS OF A RESIDENTIAL STREET

A street refers to a linear space enclosed by buildings which can contain a road (Khalaf & Ja` Afar, 2020). A residential street provides access to residences and destinations, accessible with various types of vehicles, while also providing a place for human interaction (Elsawy et al., 2019). According to Harvey & Aultman-Hall (2015), when referring to the appearance of a street, one is referring to urban design: environmental characteristics at smaller spatial/public scales with practical contributions. For example, space allocation to vehicles, sidewalks and aesthetic conditions affecting quality of experience. According to Surinta (2023), this can be understood as the 'streetscape' which relates to physical features along the street, while it is also about the design and condition of the street. Streetscape qualities consist of five operationalized qualities of urban design: Imageability, Enclosure,

Human Scale, Transparency and Complexity (Ewing et al., 2016). However, measuring the urban design quality of a 'car-free' streetscape is beyond the scope of this study; in this case, it is about identifying the design of streets that can be considered a 'car-free' street. Nevertheless, how may the urban design characteristics of a 'car-free' residential street be furthermore defined?

2.1.2 RESIDENTIAL STREETS FROM A HUMAN-SCALE URBANISM PERSPECTIVE

The rationale for this research is predicated on the process of rethinking the configuration of current car-dominated residential streets, which corresponds to how Bertolini (2020) describes this challenge: it is about achieving ‘’streets for people’’ rather than ‘’streets for traffic’’. In addition, it revolves about the question of how a (residential) street should serve its function (Elsawy et al., 2019). After studying real-world experiments in which (parts of) streets were temporarily repurposed to create more space for active mobility and social and economic activity, it was found that these experiments had positive impacts on, among others, the share of active transportation, safety, social interaction and physical activity (Bertolini, 2020). For example, re-purposing parking space by temporarily transforming on street parking space into a public space by offering amenities like bicycle storage racks, seating and public art, in addition to ‘play streets’; closure of streets to motorized traffic to allow children have more space to play (Bertolini, 2020). In addition, enhancing the walkability in neighborhoods, the condition of parks and playgrounds and ensuring the provision of sufficient infrastructure for active transportation is in all probability likely to have a favorable effect on the physical activity of adults and children (Smith et al., 2017). Sauter and Huettenmoser (2008) have found that the influence of street structure is more important than the social structure of an individual in enabling personal development, contentment and social integration within a street. Also, good streetscape design influences the accessibility and active socializing of a neighborhood (Abass & Tucker, 2020).

Consequently, considering from a human-scale urbanism perspective, a street should also be utilized and designed for other urban functions than traffic, such as leisure, safety, active coexistence and livable areas creating a ‘street microclimate’ (Bertolini, 2020; Wiersma & Bertolini, 2024). Therefore, several theoretical concepts have been identified that relate to residential street design focusing on human-scale development, often to enhance livability:

(I) Livable streets: a street could serve as seven functions, including the street as a place of play and learning, as a green and pleasant land and as a community. The street is a place where humans are seen as the center of the street to improve livability. Based on these, eight characteristics of a livable streets were defined including: street life (volume and diversity of pedestrians), social interaction (interaction between residents) and physical- environmental attributes (low air and noise pollution, paving, furniture and maintenance) (Elsawy et al., 2019). Physical characteristics of a livable street consists of ten factors, including street greenery, seating, width of the sidewalk and street segment lengths (Abdulmughni et al., 2021)

(II) Sustainable streetscapes: the role of sustainable streetscapes is to provide an attractive and safe sustainable environment. Social and economic interactions are a collective goal of sustainable streetscape design and are therefore aimed at improving environmental quality and supporting social well-being by creating streets which, among others, encourage walking, social interaction and outdoor activities. Implementing sustainable streetscapes can create more livable communities through elements such as sidewalks, trees and landscape strips, street furnishing, bicycle facilities and public art. To conclude, when designing a sustainable streetscape, the four main principles of a sustainable streetscape should be taken into account: the urban, social, economic and environmental principles (Rehan, 2019).

(III) Shared Space Street (SSS): the concept of a Shared Space Street goes further than just prioritizing the street for pedestrians over vehicles. Shared spaces can be used as a mode to promote the sense

of community and neighborhood form through facilitating and prioritizing walkability. SSS facilitates creation of livable places through encouragement of walkability and well-connected street. There are four main principles as measures for effectiveness of shared space streets: pedestrian prominence, distinctive and attractive public place, inclusive design and location and connectivity, each with their own characteristics (Jayakody et al., 2018).

(IV) Innovative streets: Innovative streets seek to enhance urban mobility and urban livability through innovation since they operate at the interface of both. In addition to transportation and commuting, an urban street serves as a place for connectivity and recreation. Innovative streets related to urban mobility include smart street infrastructure, such as street parking, smart furniture and smart lighting. Innovative streets regarding urban livability involve street activities, social interaction, active travel and human-centered street design, such as street width, sidewalk, seating, street signage and street greenery (Rui & Othengrafen, 2023).

(V) User-friendly streets: a street that is easy to use, fulfills the needs of all users and is accessible and safe. User-friendly streets relate to three main theories: inclusive environments, responsive environments and livability. The street is associated with walkability and a livable environment; a user-friendly street fulfills the need of its users through the quality of built environment in terms of physical, functional, social quality and meaning. They consist of either physical characteristic such as enclosure and unity, and qualities encouraging people to use that space through different uses and activities and comfort and convenience (Khalaf & Ja`Afar, 2020).

In addition, according to Stavroulaki & Pont (2020), other local physical factors related to a street that promote livability are:

1. Features related to traffic volume and speed (e.g. traffic calming and narrowing vehicles lanes)
2. Street design features (e.g. pavement quality, greenery, water (management) and shading)
3. Promoting non-motorized active travel, prioritizing pedestrians, bicycle lanes and shared spaces
4. Mixed-use and ground-floor pedestrian used (e.g. restaurants and cafés)
5. Building morphology, scales and visual enclosure
6. Safe crossings for pedestrians

All independent concepts are intended to enhance the livability of a street. They advocate for the need for, and importance of a street being not only designed for mobility, but also to be a safe, attractive and a livable place. The role that cars play in the street varies greatly depending on the concept, ranging from the complete absence of cars to more intelligently facilitate and utilize the space taken up by car traffic. Nevertheless all concepts intend to create and transform streets to green, attractive, safe, sustainable, comfortable, healthy and user-friendly environments that encourage and enhance social interactions, the sense of community in a neighborhood, accessibility by active mobility modes, and create opportunities for recreation, social interaction and street activities through human-centered physical environment design (Bertolini, 2020; Elsawy et al., 2019; Abdulmughi et al., 2021; Rehan, 2019; Jayakody et al., 2018; Rui & Othengrafen, 2023; Khalaf & Ja`Afar, 2020; Stavroulaki & Pont, 2020). In fact, precisely by creating spaces supporting social interactions as well as a positive social atmosphere in a street, rather than serving as a through-way, increases the public acceptance of car-free street interventions (Marcheschi et al., 2022).

2.1.3 DEFINITION CAR-FREE RESIDENTIAL STREET

Building on all the aforementioned concepts, definitions and additional literature, the following definition of car-free residential streets has been formulated:

'A residential (or mixed-use) street that does not accommodate cars and where public space is utilized for other urban features'

This definition is similar to that of the definition of "visually car free" development as described by Morris et al., (2009), in the sense that a residential car-free street an area does not accommodate cars, which however does not directly mean that this will directly discourage car ownership, as parking can be provided in other ways. Nevertheless, a car-free residential street allows for a traffic-free intermediate environment providing (limited) parking separated from the street on which a residence is situated, drawing upon the definition of Melia et al (2011). In order to identify car-free streets in practice, the decision-making of whether a residential street is car-free or not can be made in accordance with the following two factors: (I) A residential street is considered 'car-free' when the car is entirely absent within the streetscape (visually car-free), and (II) the public space contains at least one or more of the following four urban features including any of the variables shown in Table 2.

Table 2
The Four Urban Features

Urban feature	Variable	Reference
Greenery	• Green areas • (Native) trees • Landscape strips • Planters • Water	(Jayakody et al., 2018) (Elsawy et al., 2019) (Rehan, 2019) (Stavroulaki & Pont, 2020) (Abdulmughi et al., 2021) (Rui & Othengrafen, 2023)
Accommodating active modes of travel	• (Wide) sidewalk(s) • Accessible ramps • Bicycle path(s) • Bicycle storage facilities	(Jayakody et al., 2018) (Elsawy et al., 2019) (Rehan, 2019) (Khalaf & Ja` Afar, 2020) (Stavroulaki & Pont, 2020) (Bertolini, 2020) (Abdulmughi et al., 2021) (Rui & Othengrafen, 2023)
Engagement	• Play places • Open air/spaces • Seating • Restaurant/bars/café spaces • Exercise equipment	(Jayakody et al., 2018) (Elsawy et al., 2019) (Rehan, 2019) (Stavroulaki & Pont, 2020) (Bertolini, 2020) (Rui & Othengrafen, 2023)
Street furniture	• Adequate seating • (Smart) lighting • Trash receptacles • Signage	(Jayakody et al., 2018) (Elsawy et al., 2019) (Rehan, 2019) (Bertolini, 2020) (Stavroulaki & Pont, 2020) (Abdulmughi et al., 2021) (Rui & Othengrafen, 2023)

A residential street where a car can reach a residence for a 'drop-off' is technically designed to accommodate a car (Melia et al., 2014). However, this type of residential street is regarded as a car-free residential street only if parking is prohibited and if at least one urban feature, other than accommodating an active mode of travel, is present. This considering that a residential street designed to accommodate cars is generally also accessible to pedestrians and cyclists. A residential street that provides space for both parked cars and other urban features is not considered a car-free street.

Defining a car-free street was essential given that this specific topic is lacking in current literature, despite the use of various notions when referring to no or lesser cars such as 'car-lite', 'car-low' and 'car-reduced'. Furthermore, the interpretation and notions used in the literature differ depending on the spatial scale and context and therefore also the substance. Regardless of the versatile definitions presented, core principles remain equivalent: no or fewer cars in certain environments. Rather than a disagreement or debate among academics, it is more a case of a lack of knowledge which has now been addressed. The aforementioned definition can therefore serve as a framework for discussing the concept of a car-free street, as well as a basis on which to further develop this concept.

2.2 CAR DEPENDENCY

The concept of 'car dependency' is a much-encompassing phenomenon with no consensus on its definition throughout the literature (Cremer-Schulte et al., 2024). It is a multifaced, complex, elusive and widespread concept open to various interpretations (Muñoz et al., 2024; Van Eenoo, 2025; Mattioli et al., 2016). Research on car-dependency can be situated in a societal context caused by increasing concerns over traffic safety, environmental deterioration and other negative effects on the current society (Van Eenoo, 2025). In this, car ownership functions as the most important factor affecting car use (Saedizand et al., 2022). However, car use and ownership remain to exist despite provision of alternative transportation methods due to the attractiveness and utility of a car (Metz, 2023; Newman & Kenworthy, 2015; Mattioli et al., 2020).

2.2.1 CONCEPTUALIZATION

According to Goodwin (1995), car dependence is a process rather than a state that occurs at both the individual and social level. A great number of individuals have structured their everyday lives around their cars and therefore are reliant on them when carrying out any kind of activities. However, an average level of car dependence cannot be defined as there are multiple differences in the extent to which people are dependent on the car caused by differences in individuals, types of trips and types of situations that are all affected by the individual and social level. Mattioli et al. (2020) took the concept a step further and approached it as being partly influenced by political and economic factors that constitute and perpetuate car dependence, under the pretense of a 'car-dependent transportation system': ''one in which high levels of car use have become a key satisfier of human needs, largely displacing less carbon-intensive alternatives'' (Mattioli et al., 2020, p. 2). Drawing on this definition and considering four conceptualizations of approaches to investigate car dependence, Van Eenoo (2025, p. 12) proposes the notion of a car-dependent society ''being an outcome of the system of automobility characterized by the dominance of the car in meeting human needs''. This dominance, characterized by high numbers of car use and ownership, resulting from silently accepted and substantiated car-oriented land use patterns and both a perceived and actual reliance on the car for every day and occasional activities. Cremer-Schulte et al. (2024, p. 180) defined car dependence through the capabilities approach, the concept of motility and accessibility: ''Car dependence is the extent to which an individual is incapable of participating in location-based activities without the car in a satisfactory way''. External and internal components then influence the (in)capability, ranging from personal norms to land use systems to the social environment. Mattioli et al. (2016) argue that the concept of car dependence cannot be adequately conceptualized and therefore the concept should be approached by drawing on sociological concepts in which there are three understandings and level of analysis of car dependence. Car dependence as (1) an attribute of individuals (micro), (2), an attribute of trips, activities and practices (meso) and (3) an attribute of society and the built environment (macro). This perspective is central to this study because it allows to examine the impact of living on a car-free street from three different but interdependent perspectives in addition to being deeply grounded in the academic car-dependency

realm. These understandings of car dependency will now be explained in more detail per level of analysis, starting with the micro level.

(1) Micro level

From a micro level understanding, car dependency is understood as an attribute of an individual in which a distinction can be made between 'conscious' and 'structural' dependence. In general, this conceptualization refers to "car dependent individuals'', ''psycho-social car dependence" and a ''car reliant and addicted person'' (Mattioli et al., 2016, p. 57).

Conscious car dependent individuals rely on their car but would be able to undertake their journeys by alternative modes of transportation, while a 'structural' car dependent individual rely on their car because there are no (qualitative good) alternatives (Mattioli et al., 2016). However, despite the availability of alternative transportation options, psychological factors including having strong affirmative attitudes toward car use and ownership do not automatically result in the acceptance of policies on sustainable transportation. Therefore, subjective factors are crucial in understanding car dependency (Aumann et al., 2023). Structural car dependency must be accompanied by supplementary approaches since the structural limitations responsible for car dependence are usually independent of individuals, relate to the meso and macro level (Mattioli et al., 2016).

Personal conditions and socio-economic factors such as age, gender, the household composition, income, employment status and education affect car use and ownership, which vary not only by the individual, but also by other spatial contexts and across time (Muñoz et al., 2024; Zhao, 2011; Cremer-Schulte et al., 2024; Saeidizand et al., 2021). This also includes the presence of a physical or mental disability and whether an individual is in possession, for example, of a bicycle or public transportation ticket or subscription that affects an individual's ability to either use or disregard the car (Cremer-Schulte et al., 2024). Thus, at the individual level, car dependency can be evidenced and sustained by users' preferences and attitudes, shaping their decisions depending on their personal circumstances (Muñoz et al., 2024). Several studies have investigated precisely which subjective individual factors influence car dependence and underlying factors determining car use and ownership which are highlighted below.

According to Cremer-Schulte et al. (2023), personal norms, (perceived) social norms, perceived security and preferences and attitudes towards transport modes are individual subjective features, affecting car dependency. These may influence individuals' perceptions of external factors which can sustain car related behavior. Moreover, experience of using a car can both negatively and positively adjust one's attitude toward it. However, the more car driving is ingrained in an individual's system, the more difficult it is to modify it: it is a process of habituation (Cremer-Schulte et al., 2023; Muñoz et al., 2024). Yalachkov et al. (2014) accordingly refers to this as 'the compulsive habit of cars', in which understanding and responding to breaking this habit, is crucial to counter car dependence: ''It is unsurprising that simply providing alternative urban transport options or applying penalties for unnecessary car use may not be sufficient to reduce the car dependence of contemporary cities'' (Yalachkov et al., 2014. p. 228).

Furthermore, conscious car dependence may result from car use being trendy, experiencing adrenaline and other feelings and as means of a status (Muñoz et al., 2024). Soza-Parra and Cats (2023) delved deeper into the role of personal motives affecting car use and ownership and found five subjective factors:

(I) *Instrumental motives and autonomy* revolve around having a perceived feeling of control over a person's own life, the degree of autonomy and a feeling of freedom. In addition, traveling by car is generally associated with a higher level of comfort in being protected from the weather, being

able to travel seated and separately from fellow travelers, and having the ability to carry sizable luggage (Soza-Parra and Cats, 2023; Metz, 2023; Van Eenoo and Boussauw, 2023). In addition, for some using and owning a car saves time by being able to combine destinations during a single trip, it is the most economical and fastest way to travel, and it offers flexibility in managing daily family life with (young) children (Selzer & Lanzendorf, 2022).

(II) *Affective motives* refer to the role of affectivity toward car use and ownership which becomes more comprehensible when translated into statements by car users such as ''I love my car'' and ''driving gives me a kick''. Individuals tend to have positive attitudes toward car ownership and use resulting in more car ownership and usage. These affective motives are influenced by every emotion and thought generated by the use and ownership of a car in an individual's life, starting from childhood (Soza-Parra and Cats, 2023).

(III) *Symbolic motives* deal with the symbolic value one associates with a car. It is about social status and self-identity in which car ownership or use is seen as a signal of success; it gives prestige, pride and self-esteem (Soza-Parra and Cats, 2023; Metz, 2023).

(IV) *Social norms* are referring to both descriptive and injunctive norms which form individuals' understanding of what is acceptable or expected based on beliefs, attitudes and behaviors of others in a group or society. Car ownership and use is both expected and seen as normal and commonly associated with becoming an adult where these (perceived) social expectations are affected by the motives above (Soza-Parra and Cats, 2023).

(V) *Environmental motives* involve motives related to 'pro-environment' behavior that frequently results in less car use and ownership. Individuals tend to have pro-environmental norms, an interest in climate concerns and a sense of awareness to which they adjust their behavior. Individuals who are concerned with environmental motives are more frequently using alternative transportation and are prone to engage in carsharing concepts (Soza-Parra and Cats, 2023).

(2) Meso level

The meso level of car dependency can be considered as an attribute involving trips, practices and activities and encompass various factors affecting car dependency which are ignored at both the micro and macro levels. This includes the role of materials, competences and issues of timing on the ability to carry out practices (Mattioli et al., 2016). The meso level conceptualization therefore relates to ''car dependent trips'', ''car dependent activities'' and ''a car reliant activity or journey'' (Mattioli et al., 2016, p. 57). The relevance of understanding this approach is due to the persistent existence of car-dependent practices, even in a city that provides several alternative transportation options (Van Eenoo & Boussauw, 2023). Examples of car dependent practices are among others related to transporting cargo, caring, leisure, commuting and maintaining social relationships. This includes (heavy) shopping, transporting children as well as the physically challenged, undertaking hobbies, visiting family and friends and commuting (Goodwin, 1995; Mattioli et al., 2016; Van Eenoo & Boussauw, 2023; Muñoz et al., 2024; Cremer-Schulte et al., 2023; Selzer & Lanzendorf, 2022). However, a distinction can be made regarding car dependent journeys to the extent whether undertaking a practice is dependent on the use of a car (Mattioli et al., 2016). Van Eenoo & Boussauw (2023) made the following categorization of car-dependent practices:

(I) *Practices not depending on driving a car:* Car independent practices occur frequently in the inner-city context, which is strongly influenced by, among others, mobility policies, including bicycle infrastructure, parking fees and car restriction, which make alternative modes of transportation relative to the car seen as being more practical and feasible. In addition, meanings towards the position of cars, for example, 'cars don't fit in a historical city center' also contributes to less car dependent practices (Van Eenoo & Boussauw, 2023). These spatial and

infrastructural materials are essential because when everyday destinations can be reached by other means, car-use can become redundant. The more this infrastructure is provided, and the more people own the right materials to use other modes, the fewer people will use cars, where autonomy, flexibility and freedom are then associated with walking and the use of bicycles and public transport rather than cars (Selzer & Lanzendorf, 2022).

(II) *Car dependent practices which do not require private car ownership:* Non-spontaneous but planned occasional trips are typical of car-dependent trips that do not require a private car which is related to its cargo function and ability to reach rural areas. Examples of such practices are garbage disposal, bulk purchases, weekly grocery shopping trip or a weekend trip. These involve trips with a predefined schedule that also can be carried out by, for example, using a shared car or arranging home delivery and pickup (Van Eenoo & Boussauw, 2023).

(III) *Practices requiring strong adjustments or risking disintegration without car use:* Car practices that remain car dependent are characterized by autonomy, flexibility, caring and cargo continuing to dominate, in addition to factors such as access to rural areas and performing practices overnight. Reducing car dependent trips can be constrained by, for example, lack of, or inconvenient travel times and frequency of public transport causing more dependence on the car. To make these practices less car-dependent, substantial changes are needed in terms of land use, the facilitation of alternative transportation but also people's lifestyles which may result in no longer being able to perform a particular hobby, being forced to switch jobs or relocate (Van Eenoo & Boussauw, 2023). The dependence and use of automobiles is therefore justified due to a greater spatial reach by being able to reach rural areas that are either too far or cannot be reached by other modes of transportation, also showcasing a lack of comparable equivalents (Selzer & Lanzendorf, 2022).

All car-dependent practices are intricately interconnected with both individual factors (e.g. habits and attitudes) as well as societal factors (e.g. land-use and culture), which ultimately affects the extent of a car dependent practice (Mattioli et al., 2016).

(3) Macro level

The macro level emphasizes the structural factors that complicate the reduction of car dependence where car dependency is seen as an attribute of a society. In this, the built environment in a broader context plays a vital role such as land-use policies and transportation systems (Mattioli et al., 2016; Cremer-Schulte et al., 2023; Muñoz et al., 2024; Zhao, 2011), alongside a car culture being another structural factor that perpetuates car dependency (Mattioli et al., 2020; Muñoz et al., 2024). This macro level conceptualization therefore reflects "a car dependent city", ''a car reliant society" and ''car dependent locations'' (Mattioli et al., 2016, p. 57). The correlation between car dependency and the built environment is a crucial but much encompassing notion. Therefore, factors at different spatial scales that can affect car dependency are first discussed followed by the relevance of understanding and dealing with the car culture evident in contemporary societies.

(I) *Built environment:* Land use patterns consist of the spatial distribution, activity characteristics and residential location of individuals that affect the ability to engage in certain activities, which include recreation, living and working (Cremer-Schulte et al., 2023; Selzer & Lanzendorf, 2022; Zhao, 2011). A higher degree of car dependency is often related to scattered low density use and stronger zoning policies forcing individuals to travel farther and more frequently to fulfill their (daily) necessities (Mattioli et al., 2016; Muñoz et al., 2024). It addresses factors such as the diversity, proximity, density and accessibility of different facilities, activities and buildings, which then also affect factors such as job-house ratio, employment density and population density (De Gruyter et al., 2023; Muñoz et al., 2024). For instance, it has been shown that cities and

areas with higher residential density, higher levels of mixed-use with a focus on transit-oriented development led to less car use (Saeidizand et al., 2021; Muñoz et al., 2024). In addition to land use patterns, the accessibility of various facilities and locations is strongly determined by the quality and provision of transportation systems which captures the presence of transportation modes and their characteristics. This consists of both the physical infrastructure, as well as the quality of the transportation mode(s) provided such as the frequency, safety and costs (Cremer-Schulte et al., 2023). In a car-dominated city or society, infrastructure and facilities are designed to serve cars, which includes paved roads and parking lots automatically resulting in increased car use (Mattioli et al., 2020). For instance, at the street level, it appears that there is a correlation between car ownership and the increased width of a street (Muñoz et al., 2024). However, it has been proven that when alternative transportation is emphasized and provided, car use naturally decreases. People are more likely to use a car when living distant from public transportation and built environment factors such as density affect car use solely when accompanied with the provision of public transportation (Saedizand, et al., 2021). In addition to public transportation, the use of bicycles or walking is significantly influenced by, for example, the presence and width of bicycle and pedestrian paths and clearways combined with car parking costs in addition to several additional measures in the built environment to reduce the attractiveness of the car while making alternative modalities more attractive (Gruyter et al., 2023). The presence of these car independent spatial and infrastructural materials is essential in order for an individual to be capable of accessing daily amenities on foot, by bicycle, or public transportation (Selzer & Lanzendorf, 2022). However, public transportation and active mobility is often not deemed feasible under certain levels of density (Mattioli et al., 2020), demonstrating the importance in understanding interdependencies between the provision of alternative transportation modes and land use patterns in reducing car dependency. Thus, the design and allocation of land use patterns and spatial materials within the built environment influence car use as well as attitudes (Saeidizand et al., 2021; Van Wee et al., 2019).

(II) *Car Culture:* A car culture entails much more than simply using or owning a car, as it is about preferences for getting around and engaging in daily activities. It deals with individual but widely shared perceptions about freedom, flexibility and convenience associated with car use and ownership that eventually led to car-centric development (Mattioli et al., 2020). The establishment and continuation of this culture is tightly related to the decision-making process of land use; spaces designated for cars, reinforce car use and thus strengthen the car culture. A pitfall of such a culture is that motorists continue to use the car despite living in urban areas with walkable streets, bicycle path networks, and a functioning public transportation system. Moreover, it creates political hurdles that constrain attempts to provide alternatives to car use, often resulting in resistance (Mattioli et al., 2020). Transcending attitudinal barriers among planners and policymakers and for those who are yet to become accustomed to a changed streetscape, presents a significant challenge in shaping society's changing urban transport systems (Brezina & Emberger, 2017).

Nevertheless, a transformation is unfolding around this car-centered culture, a so-called shift to a new mobility paradigm aimed at more sustainable, livable and healthier cities (Marcheschi et al., 2022; Nieuwenhuijsen, 2021). For instance, more often discussed is a fairer distribution of road space in which the street is considered a place of injustice where 'reclaiming the streets' is required (ITF, 2021; Nello-Deakin, 2019). Regardless of which planning culture is prevalent, it is strongly influential in determining the degree of car dependency since it affects deciding factors in all three micro, meso and macro levels (Mattioli et al., 2020). It is likely, for example, that norms, values and habits at the individual level (micro), the functioning and location of certain activities (meso) and the design of the built environment (macro) will change when decisions are made from a different urban planning standpoint. An overview of all levels with their corresponding characteristics is provided in Table 3.

Table 3
Overview Characteristics Per Level of Car Dependency

Level	Scale	Influential Factors	Example
(1) Micro	Individual	• Personal and Socio-Economic Conditions • Autonomy • Social Norms • Instrumental, Affective, Subjective and Environmental Motives.	• "Car dependent individuals'' • ''Psycho-social car dependence" • ''Car reliant and addicted person''
(2) Meso	Circumstantial	• Trips • Activities • Practices	• ''Car dependent trips'' • ''Car dependent activities'' • ''A car reliant activity or journey''
(3) *Macro*	Society	• Land-use • Policies • Transportation systems • Spatial and Infrastructural Materials • Car Culture	• "A car dependent city'' • ''A car reliant society" • ''Car dependent locations''

Noot: Levels of Car Dependency as Conceptualized by Mattioli et al. (2016)

2.2.2 OPERATIONALIZATION

Whereas there is no consensus in academia regarding the definition of car dependency, neither is there a consensus on the operationalization and thus measurement of the concept (Cremer-Schulte et al., 2023). Muñoz et al. (2024) identified five operationalization trends namely car dependence as (1) car use and ownership, (2) an accessibility outcome, (3) subjective perceptions, (4) a modelling of choices and (5) an explanatory variable. These trends could all be utilized to reflect the extent to which an individual is car dependent.

Central to this study is the operationalization trend of depicting car dependence as subjective perceptions, since this perspective is one of the most straightforward ways to investigate car dependency (Muñoz et al., 2024). In addition, so called 'self-reported levels' of car dependency and 'people's own assessment of their reliance on cars' in forms of statements provide a prompt and more intuitive approach for gathering information about the individual's perceived level of car dependency (Cremer-Schulte et al., 2023; Zhao, 2011).

Whereas in other operationalizations car dependence is expressed in, for example, car mileage, car ownership, motorization use and the lack of accessibility, car dependence as subjective perceptions is reflected on an attitudinal way of approaching car dependence. It involves behavioral and perceptual aspects of the extent to which individuals perceive themselves as being car dependent and how herein experiences in the broader sense determine preferences as well as the difficulty or ease of performing behaviors leading to travel mode choice (Muñoz et al., 2024). Respondents indicate for instance whether they feel dependent on the car which is instrumental in understanding how dependent individuals perceive themselves and which factors contribute to a specific perception (Cremer-Schulte et al., 2023). It is however essential to relate this approach to objective spatial information such as amenities,

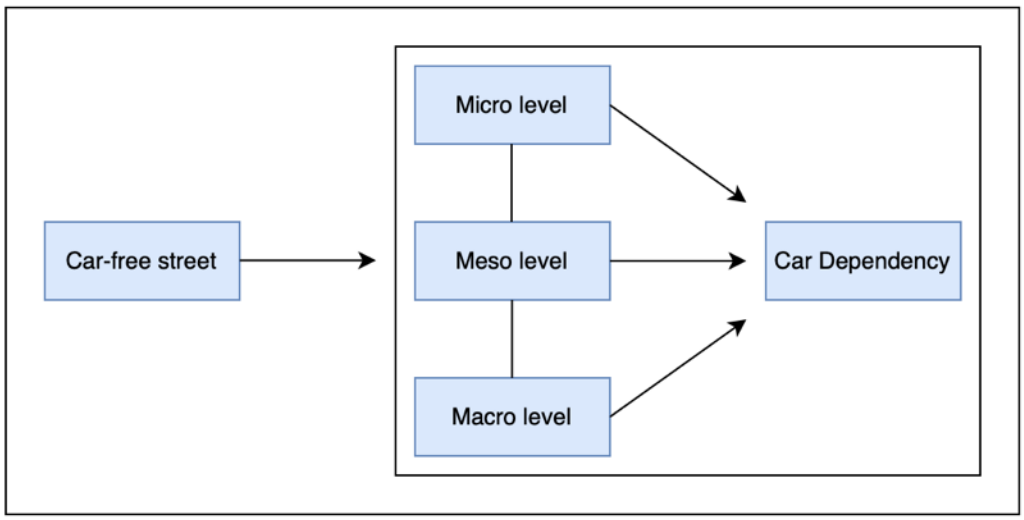
transport supply and spatial characteristics, as these influence and create the perception of individuals (Muñoz et al., 2024).

Thus, in this study, car dependence is measured by self-reported car dependence through a survey, using the full set of components (based upon factors through the micro, meso and macro approach) where additional data for external components is also gathered through self-reported indicators.

2.3 CONCEPTUAL FRAMEWORK

Figure 1 provides a visual illustration of how the core concepts central in this study are related. Car dependency is divided into three different levels of analysis in which living on a car-free street affects the degree of car dependency.

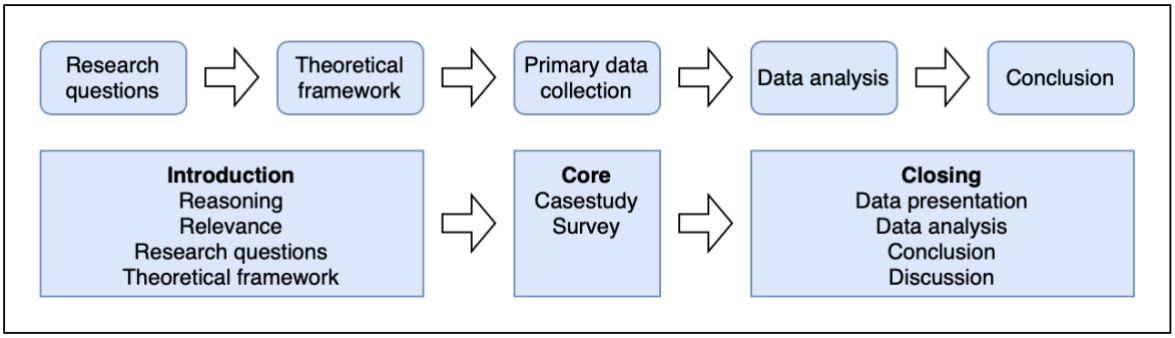
Figure 1
Conceptual Framework



3. METHODOLOGY

A mixed methods approach was used in answering the research questions regarding the subjective perceived car dependency of residents living on a car-free residential street. This involved desk research consisting of a literature review and field research using a survey which included both closed and open-ended questions distributed on several car-free residential streets functioning as case studies. An overview of the research design is given in Figure 2. The applied methodology is discussed in more detail below starting with the data collection, followed by the data analysis.

Figure 2
Research Design



3.1 DATA COLLECTION

3.1.1 LITERATURE REVIEW

The concepts of a 'car-free street' and 'car dependency' are central to this research and have been defined using a 'scoping literature review' focusing on clarifying key concepts and definitions in the literature in addition to identifying key characteristics of factors related to a concept as described by Munn et al (2018). Academic literature was retrieved using the 'Scopus' and 'Google Scholar' databases and consists of articles, reports and book chapters.

In defining car dependency, the emphasis was placed on identifying its differing definitions and conceptualizations and selecting one as a foundation to be adopted in this research. In addition, literature was used to identify and elaborate on relevant factors affecting car dependency in different forms and contexts. Regarding car-free residential streets, literature was used to source and outline related literature on car-free and residential streets from a New Urbanism perspective with a focus on livability, upon which the new-established definition of a 'car-free residential street' is grounded. Additional data that has been retrieved was used in locating applicable car-free streets in the case study city of Amersfoort and in designing the survey.

Since livability within a street is a comprehensive subject, and residential streets are only one component of a broader city network (Harvey & Aultman-hall, 2015), it is important to articulate the scope used, with regards to livability, to clarify what is included and excluded in this study:

(I) Factors related to improving livability in streets were solely used to provide substance to the definition of a (car-free residential street. Hereby, the focus was put on the physical appearance of both environmental features of urban street design and qualities of urban spaces in residential streets. This did not involve measuring the effectiveness of these elements or the appropriate way to implement them, as has been done in several studies that have been identified (Rehan, 2019; Elsawy et al., 2019; Rui & Othengrafen, 2023).

(II) Measures for improving livability related to both the car, such as parking and traffic calming measures were not included, simply since they cease to be relevant when referring to a car-free street. Also, the physical characteristics of homes, such as morphology, height and sense of visual enclosure were not included since the emphasis of this study is on street design only.
(III) The emphasis was placed on identifying factors located on a residential street and not on a neighborhood or city scale. Factors that therefore affect the livability of a street but are physically located outside of the street were not included in providing substance to the interpretation of a car-free residential street such as the proximity, density and diversity of amenities (Ewing et al., 2015; Elsawy et al., 2016). These factors are however included in the distributed survey since the proximity, density and diversity of amenities influence the subjective perception of an individuals' car dependence (Mattioli et al., 2016; Muñoz et al., 2024).

3.1.2 CASE STUDY

To investigate the subjective perceived car dependency of residents in car-free streets, a case study was employed. The target group of this research is located at specific locations which needs to be reached in order to obtain the right insights. A case study in this research is also relevant due to the research objective which aims to explain how a present social phenomenon works in practice, subsequent to why the 'how' research questions were formulated (Yin, 2009; Meyer, 2001; Baxter & Jack, 2008). Furthermore, a case study makes it possible to include context-specific circumstances in the research, wherein this research is specifically focused on such contextual situations, namely car-free streets (Baxter & Jack, 2008). In fact, other spatial factors such as amenities and surrounding characteristics play an important part in the degree of perceived car dependency (Mattioli et al., 2016), which can vary from case to case. Thus, by localizing residential car-free streets, it is possible to locate and engage with residents and obtain their insights to find answers to the main research question and related sub-questions.

The case study of this research is the city of Amersfoort, The Netherlands. Amersfoort was ranked "The Best City in Europe" in 2023, based on a progressive planning strategy, the happiness and health of its residents and its unique heritage (Tijd voor Amersfoort, n.d.). In addition, the city has introduced a car-restricted city center as part of the sustainable mobility strategy with the goal of keeping the growing city attractive, healthy and accessible (Gemeente Amersfoort, n.d.), followed by a new parking policy aimed at keeping a growing city accessible and livable (NOS, 2023). In 2024, the municipality experimented with the concept of the ''living street'': a street in which cars have been replaced, creating space for residents to meet and children to play (Fillekers, 2024). The 2030-2040 area vision states that Amersfoort ''embraces active mobility and public transportation'', ''limiting travel by car to keep the city accessible and livable'', and that the car ''will no longer be the central consideration in the arrangement of public space'' (Gemeente Amersfoort, 2023). In addition, the Mobility-Planning Program 2025-2035 of the municipality posits that parking will be "handled differently" and that concentrated parking will be constructed in new developments to allow "more space for green space and to meet-up" in the rest of the area.

It can be argued that the municipality of Amersfoort implements a progressive approach with the objective of maintaining and enhancing a livable, accessible and green city. These policy goals, measures and stance of the city of Amersfoort toward the car, parking and livability are in accordance with the New Urbanism perspective as adopted in this study. Also, Amersfoort is home to several car-free residential streets and is therefore considered as a relevant case study.

As a result of these developments and policy implications, parking has become a particularly sensitive topic. For this reason, when the survey was distributed, it was clearly communicated that this research is entirely unrelated to the municipality of Amersfoort and its parking policies. At the same time, the

purpose of the survey is stated clearly and understandably for everyone to avoid misconceptions. However, it could still have been possible that the results have been affected by an underlying and biased response due to dissatisfaction with the new parking policies.

3.1.3 SURVEY

To collect the necessary primary data a survey was used as these can collect information from larger groups in a population, while information is also usually well generalizable and information about attitudes are obtained that are difficult to measure by other means (Glasow, 2005). This fits within the chosen operationalization of the concept 'car dependency' as a subjective perception because this is the most direct way to investigate car dependency using the individual perceptions which they can self-report using a survey (Muñoz et al., 2024). Since the case studies and thus participants are based on selected factors from the literature, a non-probability sample is used, in the form of purposive sampling: the selection of relevant participants based on theory and foreknowledge (De Vocht, 2023). Consequently, the results are not representative of the population, and only valid within the sample.

As there is no established questionnaire to measure subjective perceived car dependence, the content of the statements and questions is modeled on the literature discussed in the theoretical framework. See Appendix 8.1 for the content and sequence of the entire distributed survey. The statements used to measure the three levels of car dependency are based on relevant topics derived from the literature review, including whether car use is considered ‘normal’ (micro), the extent to which the car is used for activities that could also be carried out by other modes of transport (meso), and the accessibility of daily amenities (macro). The descriptive and contextual questions were based on the situational context of the case studies such as the parking situation, type of house and the types of urban features within a street. The initial version of the formulated statements was discussed with peers, after which the statements were formulated more clearly to make them more understandable and accessible to a diverse target group.

Various statements involved the use of hypothetical statements as per the 'Stated Preference Technique' which, according to Borges et al. (2008), provide a valid representation of individual's own preferences in real life and thus can give a good indication of perceived car dependence. Here, the Likert scale functions as a set of questions measuring a personal trait (Boone & Boone, 2012), namely the perceived car dependence, which is the dependent variable. However, Likert scales are prone to distortion caused by, among others, response bias (Croasmun & Ostrom, 2011). In an effort to prevent any bias, statements have been framed both positively and negatively as well as formulating them neutral and indirect.

The survey was designed in Dutch using the software 'Qualtrics'. The statements contained 5 Likert-scales with strongly disagree (1) and strongly agree (5) being the most extreme options. For 3 statements, an explanatory answer was required. The survey started with an introduction of the researcher, followed by a brief explanation of the research objective, the estimated time it would take to complete the survey and the researcher's mail address for any comments or questions. The first seven questions were aimed at descriptive factors, mapping a respondent’s situation. These questions were used to differentiate between and identify relationships among the degree of subjective perceived car dependency and contextual situations.

Most of the statements were formulated drawing on the micro, meso and macro approach of car dependency to measure perceived car dependency. Statements 13, 14, 15, 16, 17 and 22 were used for other purposes. Accordingly, statements 13, 14, 15 and 22 were formulated to obtain more in-depth information about the extent to which living on a car-free street can explain and affect car dependency and to explore the extent to which a relationship exists between residing in car-free street and car

dependency (sub-question 5). Statement 16 refers to the concept of Residential Self Selection (RSS) as it is important to acknowledge the concept in the case of research about residential locations and the influence of urban space. RSS relates to the motivation of individuals who consciously reside in locations that meet their travel needs and preferences, based on built environment characteristics and personal travel-related attitudes, in addition to other factors such as housing characteristics and personal and social circumstances (Van Wee & Cao, 2020; Klein et al., 2024; Ettema & Nieuwenhuis, 2017). Living in a car-reduced area attracts certain individuals more than others, and therefore car-reduced areas are prone to residential self-selection (Klein et al., 2024). While examining whether residents have consciously chosen to live on a car-free street is not part of the study, it can potentially influence the results of the survey. In addition, it is important to include RSS to prevent overestimating the role of the built environment (Selzer & Lanzendorf, 2022). Therefore, to improve the validity and reliability of the data, RSS has been acknowledged by incorporating a question in the survey to examine whether a resident lives or moved to this street since it matches a desired mode of travel. Statement 17 refers to collecting data about factual urban information such as key amenities and surrounding characteristics which are crucial in determining subjective perceived car dependency (Mattioli et al., 2016; Muñoz et al., 2024). Finally, the last 6 questions consisted of demographic characteristics of an individual to compare survey results with. Likewise, literature has shown that precisely these personal conditions and socioeconomic factors such as age, gender, the household composition, income, employment status and education influence car ownership and use (Muñoz et al., 2024; Zhao, 2011; Cremer-Schulte et al., 2024; Saeidizand et al., 2021).

On Friday April 25, 2025, at all 741 addresses that were sampled (see Appendix 8.6), a piece of paper containing a QR code and a short text with explanation and instructions were delivered through the mailbox (see Appendix 8.2). When people scanned this QR code they automatically ended up at the online written survey which only allowed people who are 18 years or older to complete the survey as the minimum age at which you can drive a car in the Netherlands is 18 years. Two weeks after the surveys were distributed, the survey was put on hold and the total number of respondents reached 81 (n = 81) with a response rate of 11%.

3.2 DATA ANALYSIS

3.2.1 LITERATURE REVIEW

Analyzing and processing data from the scoping literature review consisted of descriptive analysis since scoping reviews are descriptive in nature (Pollock et al., 2022).

3.2.2 CASE STUDY

The city of Amersfoort is the overarching case study because the individual car-free residential streets in this city function as the actual case studies through which the primary data was collected. Based on the identified characteristics of car-free streets in the theoretical framework, specific residential streets have been analyzed through the online map service of ‘Google Earth’, a method also applied by Liu et al. (2022) to examine how streetscape affects car use. According to Biljecki and Ito (2021), street view imagery has become a helpful and important data source for geospatial data collection and urban analytics and has certainly been of value during this research process.

The decision-making of whether a residential street is car-free was based on the following factors: (I) A residential street is considered ‘car-free’ when the car is entirely absent within the streetscape (visually car-free), and (II) the public space contains at least one or more of the four urban features including any of the variables shown in Table 3. A car-free residential street where a ‘drop-off’ is possible is regarded

as a car-free residential street only if parking is prohibited and if at least one urban feature, other than accommodating an active mode of travel, is present.

Building on the aforementioned factors, an initial selection of car-free residential streets in 17 of the 33 neighborhoods in Amersfoort have been identified. The selection of streets is based on Google Earth satellite images that were available in the period of April 2025. New or under construction residential areas that were not finished or visible via satellite images at the time were not included. The selected neighborhoods collectively form the main urban district of the municipality, see Appendix 8.3 (Gemeente Amersfoort, 2021). As can be seen in Appendix 8.3 , the historic downtown of Amersfoort ('Stadskern') is not included within the first selection. It is for the most part "car-less" ('autoluw') and its spatial structure differs substantially from that of the surrounding neighborhoods. Moreover, the presence of various and diverse mixed-use facilities could cause the risk of an outlier. In addition, this mixed function complicates the ability to identify and differentiate eligible addresses through satellite images. For these reasons, the decision was made to exclude the downtown district and instead concentrate on surrounding residential neighborhoods.

A first selection was necessary due to the lack of data of car-free streets, both in municipal and national open databases. Additionally, it provided a useful impression of the number of car-free streets that needed to be addressed. An overview of this initial selection of car-free streets with a description of the neighborhood and variations in house type, parking situation and urban feature(s) per street can be found in Appendix 8.4. A total of 115 streets were selected across 14 of the 17 neighborhoods. No car-free streets were found in the neighborhoods 'Vermeerkwartier', 'Isselt' and 'De Hoef' (see Appendix 8.5). The approximate number of addresses totaled well over 2,500, a large number of relevant addresses available within the chosen area of research, even without accounting for the remaining 16 neighborhoods in Amersfoort. While this highlights the richness and potential of the available research material, this number also presented a practical challenge: distributing surveys and analyzing all case studies would exceed the available time frame of this study. Therefore, the decision was made, for the sake of feasibility, to limit the number of case studies and focus the research on a selection representative of the most distinct situations: car-free residential streets designed for other functions in addition to traffic as described by (Bertolini, 2020; Wiersma & Bertolini, 2024). For instance, there are wide variations in the layout of car-free streets that have been identified: Whereas some streets only consist of a sidewalk, others have such functions as sports fields, playgrounds and larger grassy areas.

The choice of the selected adjoining neighborhoods is grounded on the basis that it is likely that it increases the comparability of the survey data by ensuring that external variables such as daily amenities, public transportation stops, and other urban features are to some extent equally accessible. Doing so allows for better isolation of the influence of these urban amenities on residents' car dependency since these factors have an overall impact on car dependency (Mattioli et al., 2016).

Based on the initial selection, a final selection was made of car-free streets scattered throughout the analyzed neighborhoods. In addition to whether a street is car-free, the following other factors were considered in the decision-making process in selecting eligible addresses on these car-free residential streets:

(I) The front door of a house must be situated on the car-free street to be eligible.
(II) A complete row or block of houses should be located on a car-free street. A row or block of houses that is partly located on a car-free street and partly not is therefore not included. Herein, it also occurred that on the same car-free street, addresses were and were not selected due to differences in street layout across the entire street.

In addition to the selection of streets, the parking situation, type of house, types of urban features present were also distinguished directly for each street based on the literature found. Following this, all eligible addresses were identified using a cadaster map and identified the number of addresses per street. An overview of all these car-free streets with corresponding characteristics and numbers can be found in Appendix 8.6. The pictures taken of the selected streets during the distribution of the survey can be found in Appendix 8.7.

3.2.3 SURVEY

To analyze and process all data from the surveys, the tool 'SPSS' has been used. SPSS is a user-friendly software which can handle a large set of data including several types of tests and analysis (Rahman & Muktadir, 2021). Although the study design was suitable for a multivariate regression analysis, this was abandoned due to the violation of multivariate normality (based on the skewness values, see Appendix 8.8) and the answers on the statements being nonlinear. Since multivariate regression models are sensitive to deviations from normality, in particular with smaller samples, they can substantially affect the validity and reliability of the results (Zygmont, 2023). Therefore, alternative, univariate analysis techniques were employed, namely, the Mann Whitney test (two groups), the Kruskal Wallis H test (two or more groups) and the Spearman's rho correlation (De Vocht, 2023). For the Kruskall Wallis H test, it was necessary to utilize the Bonferroni correction in which the Alpha (a = 0.05) was corrected by dividing it by the number of comparisons representing the new significant *p* value. The quantitative data has also been analyzed and presented using descriptive analysis. Furthermore, composite scores have been calculated using each of the individual statements corresponding to the level of analysis, indicating the average extent of respondents' perceived car dependence based on the scale shown in Figure 3. This implies that all composite scores lower than 3 represent that the average of respondents perceive themselves as more car-independent than car-dependent, while a composite score higher than 3 represents that the average of respondents perceive themselves as more car-dependent than car-independent.

Figure 3
Utilized Scale of Perceived Car Dependency

To conclude, the Cronbach's Alpha test has been conducted, testing the internal consistency among the survey statements which provides evidence of the reliability of the research instrument used (Croasmun & Ostrom, 2011). Statements 1-12, 18-21 and 23 were used to measure the car dependence of residents. In order to conduct this test, the answers of statements 2, 5, 7, 9, 18, 20, 21 and 23 were mirrored to make sure that all statements were in the same answer direction. Herein, strongly disagree means 'car independent' (equal to a score of '1') and 'strongly agree' means 'car dependent' (equal to a score of '5)'. The total sequence of statements to measure subjective perceived car dependence is reliable (17 items, α = .818), showing the validity and reliability of the combination of used statements within the survey (see Appendix 8.9).

The qualitative data obtained from the survey were analyzed through a thematic analysis in which the results were categorized and compared.

4. RESULTS

The survey results obtained are presented below alongside Appendix 8.10 which provides a written clarification of the percentages and frequencies for both the demographic and descriptive questions. Within the results section itself, an elaboration is provided, beginning with the results for each level of car dependency as conceptualized by Mattioli et al (2016), in addition to the results for each statement. After discussing each of these three levels separately, a section follows in which these different levels are discussed integrally. Finally, the results section addresses sub-question 5 regarding what role car-free streets play in individuals perceived car dependence.

4.1 MICRO LEVEL

At the micro level, car dependency is understood as attribute of an individual wherein they are considered either conscious or structurally dependent on the car (Mattioli et al., 2016). Table 4 displays the numbers and percentages of the distribution of respondents for statements 1-8.

Table 4

Distribution Answers Per Statements Micro Level

	Helemaal mee oneens		Oneens		Niet mee oneens en niet mee eens		Eens		Helemaal mee eens	
	Count	Row N %	Count	Row N %	Count	Row N %	Count	Row N %	Count	Row N %
1. Ik maak gebruik van mijn auto uit een gewoonte	19	23.5%	38	46.9%	16	19.8%	7	8.6%	1	1.2%
2. Ik ben mentaal en fysiek in staat om te lopen en gebruik te maken van de fiets, het openbaar vervoer of deelmobiliteit	3	3.7%	3	3.7%	4	4.9%	21	25.9%	50	61,7%
3. Ik ervaar meer autonomie en vrijheid bij het gebruik van mijn auto dan bij het lopen of fietsen	14	17.3%	28	34.6%	21	25.9%	8	9.9%	10	12.3%
4. Ik ervaar meer autonomie en vrijheid bij het gebruik van mijn auto dan bij het gebruik van het openbaar vervoer of deelmobiliteit.	9	11.1%	7	8.6%	8	9.9%	36	44.4%	21	25.9%
5. Het maakt mij niet uit waar ik mijn auto in de wijk parkeer.	25	30.9%	26	32.1%	12	14.8%	15	18.5%	3	3.7%
6. Ik zie het gebruik van een auto als 'normaal' en 'gewoon'.	7	8.6%	12	14.8%	17	21.0%	33	40.7%	12	14.8%
7. Ik ben bewust in deze straat gaan wonen omdat ik wist dat deze autovrij is.	19	23.5%	20	24.7%	14	17.3%	18	22.2%	10	12.3%
8. Ik gebruik mijn auto dagelijks.	22	27.2%	35	43.2%	8	9.9%	9	11.1%	7	8.6%

A mean score of 2.84 (*SD* = 0.69) was calculated for all respondents (see Appendix 8.13). This indicates that respondents perceive themselves on average as more car independent than car dependent on an individual level. A total of 33 respondents has an average score of 2.6 or lower while 41 respondents score higher than 2.9 on average. Seven respondents scored exactly the overall average of 2.8.

A total of twelve separate tests were conducted to examine differences in composite micro-level scores across different groups (see Appendix 8.14). Three of these yielded statistically significant results (*ps* > .05): owning a driver's license, the number of cars in a household, and the type of street on which a respondent lives. For instance, a Mann-Whitney test showed that the degree of perceived car dependence at the micro level among respondents with a driver's license (Mdn = 42.82) differed significantly from perceived car dependence among respondents without a driver's license (Mdn = 6.00). The effect found in this case is small, U = 14.00, p = .002, r = 0.34.

A Kruskal-Wallis H test revealed a significant difference in the extent of car dependence on the micro level and between the number of cars owned by a household, $\chi^2(3) = 29.71$, $p < .001$, although not among which groups. Therefore, post-hoc pairwise comparisons were performed using Mann-Whitney U tests with a Bonferroni correction applied, resulting in a significance level set at $p < .013$. The degree of car dependence when not owning a car in a household (group 1) differed significantly from owning 1 or more cars as in groups 2 ($p < .001$), 3 ($p < .001$) and 4 ($p = .012$). The difference between owning 1 car (group 2) and group 3 ($p < .001$) and group 4 ($p = .008$) is also significant. Only the differences between owning 2 or 3 or more cars and the degree of car dependence at the micro level is not significant ($p = .049$).

Using a Kruskal-Wallis H test it also emerged that the degree of perceived car dependence differed significantly between the type of car-free street where respondents reside, $\chi^2(2) = 8.98$, $p = .011$. Post-hoc pairwise comparisons using Mann-Whitney U tests with Bonferroni correction ($p > .017$) indicated that only the 'car-free with urban feature(s)' group differed significantly from the 'car-free with drop-off with urban feature(s)' group ($p = .006$), while no significant differences were found between 'car-free' and 'car-free with urban feature(s)' ($p = .055$) or between the groups 'car-free' and 'car-free with drop-off with urban feature(s)' ($p = .664$).

To conclude, at the micro level of car dependency, respondents perceived themselves as more car independent than car dependent on average ($M = 2.84$, $SD = 0.69$). This composite score only significantly differed among respondents with or without a driver's license, the number of cars in the household and the type of car-free street. This also indicates that no significant differences were found between perceived car dependency at the micro level and, for example, age, gender and the parking situation.

4.2 MESO LEVEL

The meso level of car dependency involves circumstantial factors such as trips, practices and activities that influence the degree of car dependency (Mattioli et al., 2016). Table 5 shows the numbers and percentages of the distribution of respondents for the statements 9 to 12, directed at this level of car dependency. Here it can be observed that for statement 9 nearly the same number of respondents filled in (strongly) disagree as (strongly) agree: 36 versus 31. A clear shift can also be seen in the case of statement 12 compared to statement 11, where 21 respondents changed their answer while assumably the remaining respondents stayed with their previous answer.

Table 5

Distribution Answers Per Statements Meso Level

	Helemaal mee oneens		Oneens		Niet mee oneens en niet mee eens		Eens		Helemaal mee eens	
	Count	Row N %	Count	Row N %	Count	Row N %	Count	Row N %	Count	Row N %
9. Ik gebruik mijn auto voornamelijk voor activiteiten die ik kan inplannen, zoals het vervoeren van afval, mensen en grotere objecten.	15	18.5%	21	25.9%	14	17.3%	26	32.1%	5	6.2%
10. Ik maak gebruik van mijn auto voor activiteiten die ik ook zou kunnen uitvoeren met een andere vervoerswijze.	15	18.5%	38	46.9%	11	13.6%	14	17.3%	3	3.7%
11. Ik gebruik mijn auto om op locaties te komen die niet te bereiken zijn met een andere vervoerswijze.	8	9.9%	10	12.3%	6	7.4%	48	59.3%	9	11.1%
12. Ik zal nog steeds gebruik maken van mijn auto om op locaties te komen die eerder niet te bereiken waren met andere vervoerswijze, maar die nu wel bereikbaar zijn.	8	9.9%	11	13.6%	26	32.1%	28	34.6%	8	9.9%

The mean composite score of respondents is 3.07 (*SD* = 0.60) (see Appendix 8.15) meaning that respondents at a circumstantial level perceive themselves on average more as car dependent rather than car independent. Accordingly, 26 respondents have an average score of 2.8 or lower, compared to 35 respondents with an average score of 3.3 or higher. The remaining 20 respondents have an average score of exactly 3.

To examine the differences in composite meso level scores across different groups, twelve separate tests were conducted (see Appendix 8.16). Out of the twelve tests, only two yielded statistically significant results (*ps* > .05), namely 'owning a driver's license' and 'the number of cars in a household'. In this regard, a Mann-Whitney test showed that the degree of perceived car dependence at the meso level among respondents with a driver's license (Mdn = 42.90) differed significantly from perceived car dependence among respondents without a driver's license (Mdn = 4.50). This represents a small effect, U = 8.00, p = .001, r = 0.36.

The Kruskal-Wallis H test revealed a significant difference in the extent of car dependence on the micro level and between the number of cars owned by a household, $\chi^2(3) = 23.90$, $p < .001$. Post-hoc pairwise comparisons using Mann-Whitney U tests with a Bonferroni correction were performed to examine the differences between the groups, resulting in a significance level set at $p < .013$. The degree of car dependence at the meso level for not owning a car in a household (group 1) differed significantly from owning 1 or more cars as in groups 2 ($p < .001$), 3 ($p < .001$) and 4 ($p = .004$). However, there is no significant difference between owning 1 car and owning 2 ($p = .242$) and 3 or more cars ($p = .379$). Also, no significant differences are present among owning 2 or 3 or more cars ($p = .744$).

Finally, at the meso level of car dependence, respondents perceived themselves to be more car dependent than car independent on average (M = 3.07, SD = 0.60). This composite score differed significantly only for respondents with or without a driver's license and the number of cars in the household. Similarly at the micro level, no significant differences were found between perceived car dependence at the meso level and, for example, age, gender and parking situation.

4.3 MACRO LEVEL

For the macro level, car dependency is considered an attribute of society in which the built environment and societal car culture have an important impact. Table 6 shows the numbers and percentages of the distribution of respondents for the statements 18 to 21 and 23, focusing on the macro level of car dependency.

Table 6

Distribution Answers Per Statements Macro Level

	Helemaal mee oneens		Oneens		Niet mee oneens en niet mee eens		Eens		Helemaal mee eens	
	Count	Row N %	Count	Row N %	Count	Row N %	Count	Row N %	Count	Row N %
18. Ik kan dagelijkse voorzieningen bereiken zonder een auto.	1	1.2%	1	1.2%	4	4.9%	32	39.5%	43	53.1%
19. Mijn autovrije straat beperkt mij bij het uitvoeren van dagelijkse activiteiten, zoals naar mijn werk gaan, boodschappen doen, sporten en recreëren.	54	66.7%	20	24.7%	4	4.9%	1	1.2%	2	2.5%
20. In mijn omgeving (wijk en stad Amersfoort) wordt het gebruik van alternatieve vervoerswijze gestimuleerd, zoals (veilige) fietspaden, parkeerkosten voor auto's en het aanbieden van deelmobiliteit.	5	6.2%	9	11.1%	24	29.6%	32	39.5%	11	13.6%
21. Doordat ik in een autovrije straat woon maak ik vaker gebruik van andere vervoerswijze dan de auto	28	34.6%	26	32.1%	13	16.0%	8	9.9%	6	7.4%
23. Als ik in de toekomst ga verhuizen, geef ik de voorkeur aan een straat zonder autoverkeer of parkeergelegenheid, die in plaats daarvan ruimte biedt voor bijvoorbeeld groen, fietsen en speel- en sportvoorzieningen.	13	16.0%	11	13.6%	14	17.3%	26	32.1%	17	21.0%

The average composite score at the macro level is 2.42 (*SD* = 0.71) (see Appendix 8.17). This implies that, on average, respondents perceive themselves to be more car independent than car dependent on a society level. In fact, only 15 respondents score an average of 3.2 or higher versus 61 respondents with a score of 2.8 or lower in addition to the remaining 5 respondents who have an average score of 3 and thus right in the middle. The composite score at the macro level is the lowest average score of all three levels which means that on average respondents feel less car dependent at the society level than at the individual (*M* = 2.84) or circumstantial level (*M*= 3.07).

Twelve separate tests were also conducted to examine differences in composite scores at the macro level across different groups, of which only one returned statistically significant (*ps* > .05): 'number of cars in a household'. A Kruskal-Wallis H test revealed this significant difference in the extent of car dependence on the macro level and between the number of cars a household owns, $\chi^2(3) = 19.12$, $p < .001$. Post-hoc pairwise comparisons using Mann-Whitney U tests with a Bonferroni correction were used to examine these differences within groups, which resulted in a significance level set at $p < .013$. The degree of car dependence at the macro level for not owning a car in a household (group 1) differed significantly from owning 1 or more cars as in groups 2 ($p = .003$), 3 ($p < .001$) and 4 ($p = .012$). However, there is no significant difference between owning 1 car and owning 2 ($p = .042$) and 3 or more cars ($p = .019$). Similarly, no significant differences exist between owning 2 or 3 or more cars ($p = .081$).

Concluding, at the macro level of car dependence, respondents perceived themselves to be on average more car independent than car dependent (*M* = 2.42, *SD* = 0.71). This composite score differed

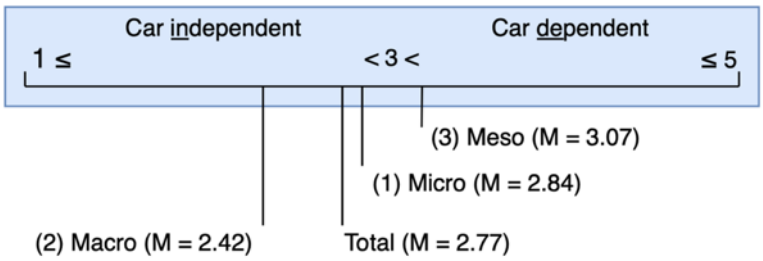
significantly only among respondents with none and 1, 2 or more cars. Thus, as was also the case with the micro and meso levels, no significant differences were found between perceived car dependence at the macro level and, for example, age, gender and parking situation.

4.4 MICRO, MESO AND MACRO LEVEL

In addition to the composite score per analysis level, the total composite score of perceived car dependence was also calculated (see Appendix 8.19). The mean composite score of the perceived car dependence of residents in car-free streets is 2.77 (*SD* = 0.58), meaning that respondents generally perceived themselves to be more car independent than car dependent. Thus, 65% of respondents (53) scored a mean composite score below 2.9 compared to 31% of respondents (25) with a mean score of 3.1 or higher. Four percent of respondents (3) scored exactly a score of 3 across 17 questions. Figure 4 provides a visual depiction of where the three individual composite values occur for each level and the total value on the scale.

Figure 4

Utilized Scale of Perceived Car Dependency with Composite Scores



In addition to the 17 statements for measuring residents' perceived car dependence, additional statements were present with other purposes, including statement 16 concerning Residential Self Selection (RSS) (see Table 7). As explained in the methodology section, this concept was included in the survey to examine whether a resident lives or moved to this street since it matches a desired mode of travel and to prevent overestimating the role of the built environment (Selzer & Lanzendorf, 2022). The results showed that just under half of the respondents (49%) disagreed with the statement versus 30% of those who answered agree. This distribution reflects that there are differences in the extent to which respondents live and have gone to live in their street, but fact is that there is a large proportion of respondents who indicated that they do not live or went to live in their street because it corresponds better to the desired mode of travel making the phenomenon of RSS in this case less present and important. However, this conclusion is solely based on the desired mode of travel and not on other factors relevant to RSS such as personal preferences and needs (Van Wee & Cao, 2020; Klein et al., 2024).

The results of statement 17, regarding whether various daily amenities are available in a respondent's neighborhood, showed that only 1 respondent disagreed, compared to 78 respondents who indicated that they did (strongly) agree. This statement was of interest since car dependence has been approached from the individual perception. Relating objective spatial information such as amenities, was therefore essential, as these influence and create the perception of individuals (Muñoz et al., 2024). Concrete information on distances, diversity and numbers of these amenities is lacking. However, these results do give a strong indication that daily amenities are in their vicinity for almost all respondents.

Table 7
Distribution Answers for Statements 16 And 17

	Helemaal mee oneens		Oneens		Niet mee oneens en niet mee eens		Eens		Helemaal mee eens	
	Count	Row N %	Count	Row N %	Count	Row N %	Count	Row N %	Count	Row N %
16. Ik woon of ben in deze straat gaan wonen, omdat deze locatie aansluit op mijn gewenste manier van reizen naar bijvoorbeeld werk of familie.	19	23.5%	21	25.9%	17	21.0%	15	18.5%	9	11.1%
17. In mijn omgeving bevinden zich verschillende dagelijkse voorzieningen, zoals een supermarkt, gezondheidszorg en andere winkels.	0	0.0%	1	1.2%	2	2.5%	38	46.9%	40	49.4%

4.5 THE ROLE OF CAR-FREE RESIDENTIAL STREETS

The survey used 4 statements, 3 of which were open-ended to provide an answer to sub-question 5 regarding what role car-free residential streets play in residents' perceived car dependence. For each statement, the results are explained in more detail. The distributions of the numbers and percentages are shown in Table 8 and an overview of all open answers given per statement and per answer option can be found in Appendix 8.20.

Table 8
Distribution Answers for Statements 13, 14 and 15

	Helemaal mee oneens		Oneens		Niet mee oneens en niet mee eens		Eens		Helemaal mee eens	
	Count	Row N %	Count	Row N %	Count	Row N %	Count	Row N %	Count	Row N %
13. Het wonen in een autovrije straat speelt een rol in het wel of niet gebruiken van mijn auto.	31	38.3%	34	42.0%	9	11.1%	6	7.4%	1	1.2%
14. Ik zal meer en sneller gebruik maken van mijn auto als ik in een straat had gewoond waarin mijn auto voor de deur zou staan.	32	39.5%	33	40.7%	10	12.3%	3	3.7%	3	3.7%
15. Omdat ik in een autovrije straat woon, ben ik anders gaan denken over de plaats van de auto in onze leefomgeving.	25	30.9%	27	33.3%	15	18.5%	11	13.6%	3	3.7%

(I) Statement 13 - Living on a car-free street plays a role in whether or not I use my car.

More than 80% of the respondents indicated that they (strongly) disagree with this statement, compared to 9% of the respondents who did (strongly) agree.

Notable was the amount of respondents who explicitly mentioned in open-ended responses that car use and living on a car-free street are completely unrelated without providing a rationale: *'Car-free does not equate to not using a car'*, *'car use is based on need for transportation, not whether it is parked in the street'*, *'my living is unrelated to using my car'* and *'it plays no role'*. Other respondents who disagreed with the statement indicated that they can use the car by having easy access to it in other ways, such as through the back door or a parking garage: *'Can get away easily through the parking garage'*, *'We have parking on our own property and so can use our car at any time'*, *'Through the back/parking garage*' and

'The car is close enough'. In addition, the reason(s) for using the car also play a role. For example, some respondents indicated that they only use the car in case of '*necessity*' and *'if there is no other way*' to, for example, '*work*' and for '*physical mobility'*, and for the transport function such as transporting a '*dog*', *'toddler and baby*'. Other reasons why respondents disagree with the statement vary from reasons related to location, size and type of home, to '*I like my car, so I like to use it'*.

For the few respondents who (strongly) agreed with the statement, it was indicated that the "car is used more consciously', '*a distance and awareness is then created anyway*', the '*bicycle is closer, faster and easier to take',* and '*a barrier to take the car'*.

(II) Statement 14 - I will use my car more and faster if I had lived on a street where my car would be parked in front.

Likewise for this statement, 80% of respondents indicated that they (strongly) disagree with the statement as opposed to 8% of respondents who (strongly) agree.

Several respondents again explicitly stated that they did not see any connection between car use and living on a car-free street: *'The use of my car does not depend on the street where I live'*, *'Because it has nothing to do with each other'*, *'My living is independent of the use of my car*' and *'a connection is being sought (!) here that does not exist*'. It is also noticeable that many respondents did not give an answer or referred to their answer at statement 13. There is also a group of respondents who indicated that no matter the parking situation, they (will) use the car: '*necessity'*, *'it takes no effort to take the car*', *'I use my car when I feel the need'*, *'I use my car daily*' and *'I use my car when I need it no matter where it is'*. There were also several respondents who indicated that they disagreed with the statements because they only use their car when they cannot get there by bicycle and because they make a conscious decision: *'I only use my car when I can't get there by bicycle'*, *'I use my car when I need to and I can't get there by bicycle*', *'I think about it'* and *'I consciously use my car'*. Respondents who (fully) agreed with the statement gave as reasons: '*convenience*', '*faster*' and *'more accessible'*.

(III) Statement 15 - Living on a car-free street has made me think differently about the place of the car in our living environment

The majority of respondents (64%) (strongly) disagrees with statement 15. Seventeen percent (strongly) agrees in addition to 19% who chose the neutral option. However, this distribution does not reflect the distribution of respondents against whether the car belongs in the living environment or not as several respondents (strongly) disagree with the statement on the grounds that they were already aware of this without being affected by living on a car-free street. For example, respondents indicated that they were '*already in favor of car-free streets and neighborhoods'*, *'find cars unbearable'*, that *'the car does not belong in a living environment'* and *'I see cars as a necessary evil, this has not changed'*. Respondents who did agree with the statement stated that '*a car-free street is more pleasant'*, *'it is wonderful not to have a car outside the door, which improves the quality of life'* and '*it is nice not to have cars driving past the house'*. Reasons such as the '*environment*' are also mentioned, in addition to the realization that '*cars get a lot of space everywhere'*, *'a lot of space is kept free for cars' and 'the car is taking up space at the expense of functions that are more useful for the benefit of others'*. A single respondent stated that they *'have gained a greater appreciation for the peace and greenery around the house'* and the possibilities to move yourself differently than by car: *'you can walk everywhere in the center of the Amersfoort'*. Finally, one respondent indicated that they found living on a car-free street '*wonderful*' and that they *'wish that to everyone'*.

Several respondents who (strongly) disagreed with the statement gave as their reason the importance of the car as it '*gives freedom, autonomy and space'*, but also that *'the car is a necessity in life'*, that '*you*

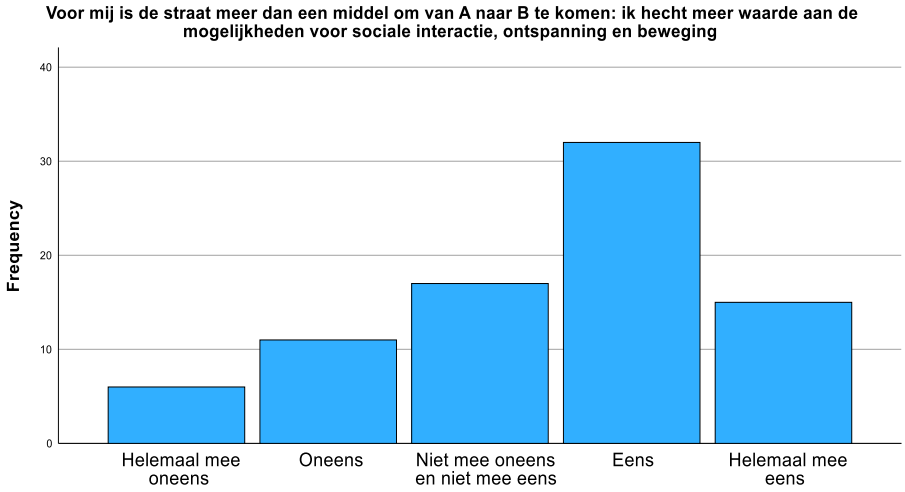
don't have a car for fun' and that *'the car has an important role to play and maintain because public transport is too expensive and inaccurate and shared mobility makes you dependent on others'*. There are also respondents who chose to disagree or don't disagree, don't agree who indicate they are not or not yet aware of the place of the car in the living environment: *'I am not that concerned with living environment'*, '*I don't* know', *'not really different'* and '*it doesn't play a role in my* life'.

(IV) Statement 22 - For me, the street is more than a place to get from A to B: I value the opportunities for social interaction, relaxation and exercise more.

Figure 5 displays a graph of the distribution of respondents regarding statement 22. It clearly shows that most respondents (strongly) agree with the statement. This evidently reveals that the majority of respondents prefer urban features other than just a road.

Figure 5

Bar Chart with Distribution of Answers Statement 22



Since the collected empirical data is neither linearly nor normally distributed, no statistical tests can be conducted to provide an answer about the causality of car dependence and the influence on it of living in car-free residential streets. However, the correlation between statements 13, 14, 15 and 22 and the composite car dependence score per level was investigated using the association measure 'Spearman's rho' (see Appendix 8.21).

An overall positive correlation was found between the different composite scores on different levels of car dependence (1 = independent, 5 = dependent) and the four statements related to car free streets (scale mirrored: 1 = independent, 5 = dependent).

At the micro level, the relationship is weak to moderate but significant at three of the four individual statements: 13 (ρ = .25, p = .026), 15 (ρ =.36, p = .001) and 22 (ρ =.38, p < .001). For statement 14, the analysis showed a very weak relationship that was not significant (ρ = .07, p = .526). The meso level involves (very) weak relationships where statement 13 and 15 are significant: 13 (ρ = .25, p = .026), 14 (ρ =.01, p = .95), 15 (ρ =.23, p = .035) and 22 (ρ =.20, p = .067). Finally at the macro level, weak to moderate correlations were found with only statement 14 not being significant: 13 (ρ = .30, p = .006), 14 (ρ =.19, p = .094), 15 (ρ =.40, p < .001) and 22 (ρ =.46, p < .001).

These statistical results indicate that individuals with a more positive attitude toward car dependence, reflected in higher composite scores, also tend to score higher on average on the four statements about the role of car-free streets. Regarding the influence of car-free streets on residents perceived car

dependence, the data suggest that individuals who consider themselves more car-dependent are, on average, less likely to attribute this dependence to living on a car-free street. This finding is supported by a statistically weak to moderate correlation, indicating that while there is some association, other factors are likely to play a more substantial role in shaping perceptions of car dependence.

This statistical approach can be substantiated using the open-ended responses obtained for statements 13, 14 and 15. Several respondents stated that living on a car-free street is entirely unrelated to, for example, owning and using a car, with the underlying reasons being traced back to the different levels of car dependency: *'I like my car so I like to use it'* (micro), transporting a '*dog*', '*toddler*' and '*baby*' (meso) and *'the car is necessary in life'* (macro). Only a few respondents did indicate that because they live on a car-free street, they (would) make other choices, for example, because of the realization that *'cars get a lot of space everywhere*' and it can act as a *'barrier to take the car'*.

Drawing on the spearman's rho rank-order correlations, it can be concluded that there is a weak to moderate positive correlation between the degree of car dependence and the influence of living on a car-free street. Based on the responses to statements 13, 14, and 15, it can be concluded that a greater proportion of respondents indicated that living on a car-free street does not play a role, compared to those who stated that it does. The reasons given differ strongly for each respondent, reflecting the complexity and multifaceted nature of the concept of car dependency. Precisely because of these diverse reasons given by respondents, combined with the statistical correlation, it can be concluded that for this sample, living on a car-free street does contribute to residents' perceived car dependence, in addition to several other factors throughout the three levels of analysis. However, the significance of car-free streets in residents' perception of car dependency depends greatly on the contextual and individual situation of a person, as well as the extent to which an individual perceives its own car dependency, causing the role of living on a car-free street to be perceived differently.

5. DISCUSSION

Several findings emerged from this study, all of which are discussed below. Given that the empirical data collected was derived from a non-representative sample, this section first examines what the results imply within this sample, before discussing the significance of the results outside the sample to the extent possible. The discussion is concluded with a section on research limitations and suggestions for future research.

5.1 IMPLICATIONS WITHIN THE SAMPLE

The average composite scores indicate respondents' self-reported perceptions of their dependence on their cars according to the scale shown in Figure 3. However, by looking at the individual statements, a lot more can be revealed about possible explanations for these results. Given that the results are relatively similar among the levels, the most interesting findings are integrally discussed in greater detail, reflecting the theoretical and social implications within the sample.

(I) Multiple statements suggest that most of the respondents' dependence on cars reflects conscious dependence rather than structural dependence. In this, respondents rely on their cars for various reasons, while indicating that they perceive their journeys could be undertaken by alternative modes of transportation (Mattioli et al., 2016). For instance, the absolute majority of respondents reported being mentally and physically capable of using modes of transportation other than cars, owning one or more bicycles, and being able to access daily amenities without a car.

(II) Furthermore, it appears that public transportation and shared mobility, as alternatives to the automobile, are generally perceived negatively. Almost half of the respondents experience less autonomy and freedom when using shared mobility and public transportation compared to cycling or walking as alternatives to the car. This may be explained by the fact that 97% of respondents already own one or more bicycles, but also by a process of habituation and the 'compulsive habit of cars' (Cremer-Schulte et al., 2023; Muñoz et al., 2024; Yalachkov et al., 2014). The same pattern is observed in statements 11 and 12, where only one respondent indicated that they would leave their car at home if a location that was previously inaccessible but is now accessible by alternative means of transportation. However, when looking at statement 1, 70% of respondents indicate they do not use their car out of habitual reasons. This reflects the complex nature of the concept of dependency, making it very interesting to investigate the extent to which perceived car dependency relates to and corresponds with actual objective car dependency.

(III) How crucial habits are becomes more obvious in statement 23, about whether people would prefer to live on a car-free street if they decided to move. The exact reasoning behind these answers is unknown, including whether it's related to car dependency, but it does indicate that getting used to certain things can play a key role in undertaking future actions. In addition, only 3% of respondents experience inconvenience in carrying out daily activities caused by living on a car-free street. This suggests that residents can carry out daily activities with or without a car and do not feel restricted by their street.

(IV) Looking at the composite scores per level in this sample, it appears that the spatial and physical environment as experienced by respondents suggests opportunities for a car-independent lifestyle in the selected car-free streets, as it scores the lowest on average. For the meso level, the opposite is true: locations or activities that are difficult or impossible to reach by other modes of transport have an increasing influence on the perceived car dependency. Additionally, a higher micro score relative to the macro score indicates that respondents perceive themselves

to be more dependent on cars than necessary in practice, according to their own perceptions. Although this correlation is not irrefutable, it does show that individual perceptions, attitudes, and experiences are an important and decisive factor in determining the degree of car dependency, which has also been confirmed in the literature (Mattioli et al., 2016; Goodwinn, 1996; Aumann et al., 2023; Saeidizand et al., 2021; Yalachkov et al., 2014).

(V) The statistically significant differences found at all three levels between possessing or not possessing a driver's license and owning no or a certain number of cars can easily be attributed to the fact that these factors are decisive in determining whether someone can use a car. However, the significant difference between respondents living on a car-free street with urban feature(s) and a car-free street with drop-off with urban feature(s) is much more difficult to clarify, especially since no significant difference exists between 'car-free' and 'car-free with drop-off with urban feature(s)'.

(VI) When considering the role of a car-free street in the perceived car dependency, both textual and statistical analysis revealed that respondents perceive this role as very weak to moderate. This weak relationship suggests that, in this sample, perceived car dependency is not solely related to car-free streets, but to many other factors that are either equally important or more important and therefore have a greater influence on the respondents' perceived car dependency. This is clearly reflected in the literature, which shows that overall car dependency is influenced by a range of different factors at different scales and therefore not just a single factor (Stavroulaki & Pont, 2020; Muñoz et al., 2024; Zhao, 2011; Cremer-Schulte et al., 2024; Saeidizand et al., 2021; Mattioli et al., 2016; Soza-Parra and Cats, 2023; De Gruyter et al., 2023; Selzer & Lanzendorf, 2022). Nevertheless, for this sample, it can be argued that living on a car-free street influences the perceived car dependency.

5.2 IMPLICATIONS BEYOND THE SAMPLE

It is difficult to interpret the significance of these results for the population, as this sample is not representative and the responses to the statements are rather superficial and lack depth. Furthermore, the absence of other research specifically targeting car-free streets hinder the comparability with findings from similar studies. Despite these limitations, a number of results from this study have emerged that correspond with or can be related to previous research and do accurately reflect current societal and theoretical themes and issues that are generally known and underlie this research, starting with the newly established definition of car dependency.

(I) The formulated definition of a car-free street is primarily grounded on a synthesis of similar literature covering various car-free spatial contexts and scales. This formulation may serve as a foundation for subsequent research to further elaborate on or identify car-free streets.

(II) For example, most respondents reported that they do not use the car on a daily basis, but that they do care about where they can park their car in the neighborhood. These results suggest that cars are thus parked and unused most of the time, which is consistent with part of the reason for this study: residential streets dominated by traffic and parked cars.

(III) The results reveal that at the macro level, residents' perceived car dependency scores the lowest on average: 2.42 (*SD* = 0.71) compared to the micro (*MD* = 2.84, *SD* = 0.69) and meso levels (*MD* = 3.07, *SD* = 0.60), although these average scores are relatively close to each other. Yet, these findings reflect the importance that simply implementing interventions in the built environment is often not enough and that, on the contrary, individual-level and trip-level interventions are also required to counter car dependency in general, something that has already been discussed frequently in the literature (Mattioli et al., 2016; Goodwinn, 1996; Aumann et al., 2023; Saeidizand et al., 2021; Yalachkov et al., 2014).

(IV) Using a series of statistical tests, no significant differences were found for all three levels of car dependency between, for example, age, gender, and education level, as well as type of residence and parking situation. However, previous research has revealed that demographic and social economic conditions, for instance, do affect the level of car dependency (Muñoz et al., 2024; Zhao, 2011; Cremer-Schulte et al., 2024; Saeidizand et al., 2021). An explanation as to why this was not the case in this study may be due to the smaller and non-representative sample.

(V) Finally, this research reveals that the concept of car dependency is indeed a very complex and encompassing concept, both in terms of its substance and process. Car dependency is influenced not by just one but by many different factors, which can also be examined in different ways. In addition, these different factors are perceived differently for each individual and context, which makes exploring them more complicated not only because of the amount and diversity of subjects but also because of the time required to understand the entire picture.

5.3 LIMITATIONS

Throughout the study, various substantive and procedural limitations were encountered that might have negatively affected the reliability and validity of the results. The most notable limitations are summarized below:

(I) Some of the open responses in the survey suggest that several respondents did not understand the hypothetical statements, as they either directly denied them or provided an unrelated or irrelevant explanation. This may be indicative of a lack of knowledge or misunderstanding regarding this topic, which calls for further research on car dependency using other research methods such as interviews or focus groups to investigate the source and understand these denials or misunderstandings. Other research methods may also be used to provide more information or explanation about the topic at that specific moment, enabling respondents to gain a better understanding of what exactly is meant by a statement or question.

(II) The survey did not include any respondents from the age group of 85 years or older, meaning that no observations can be provided in the sample concerning the car dependence of this age group. This may be due to the fact that this age group does not reside in homes on the selected car-free streets, or that they have not been mentally capable of conducting an online survey using a QR code.

(III) As mentioned before, the sample taken is not representative resulting in non-generalizable findings. Therefore, no conclusions can be drawn about the extent to which these results are representative of other residents in car-free streets in Amersfoort or in the Netherlands in general. This compromises the reliability and usability of the research results when these are drawn more widely.

(IV) Finally, the concept of car dependency is a complex and multifaceted concept that does not involve one standard of measuring. Even by breaking it down to the micro, meso and macro level, still many complexities and potential unintended consequences remain that make drawing conclusions very complicated. In addition, there are also interrelationships to deal with which makes deriving conclusions even more complicated.

5.4 SUGGESTIONS SUBSEQUENT RESEARCH

Drawing on this research, the following suggestions are given for follow-up research focused on car dependency and car-free streets:

(I) The results from this sample indicate that, on average, people perceive themselves as more car independent than dependent. Follow-up research could be targeted on to what extent this perceived car dependence corresponds to the objective car dependence using another operationalization as described by Muñoz et al. (2024) and thus to what extent this perceived car dependence provides a realistic representation of actual car dependence.

(II) This research concentrated only on residents in car-free streets. Subsequent research could conduct the same type of study that would now include residents living in streets with cars in the same area to investigate whether there is a difference in the (perceived) car dependence of residents in a street with and without cars.

(III) In this study, statements were utilized that provided answers to the sub- and main question. However, these were perfunctory whereas precisely the explanations and reasons for agreeing or disagreeing with a particular statement is interesting and can reveal a lot about an individual's motivation. Therefore, follow-up research on car dependence in general should focus much more on the explanations and motivations of the 'why' and not just the extent to which a person agrees or disagrees with a (hypothetical) statement.

(IV) Car-free in general is an emerging but relevant topic where specifically the concept of the car-free street is a concept not yet frequently addressed in academia. More research specifically on the conception and function of such a street under the pretense of human-scale urbanism and urban justice should contribute to further knowledge on this topic, to which both the dependence on cars as well as other urban challenges such as livability and more can be related.

6. CONCLUSION

This study was conducted with the purpose of finding an answer to the following research question: *How does living on a car-free residential street influence residents' perceived car dependence?*

In this regard, the objective was to investigate how residents, living on a car-free residential street, experience their car dependence and what role car-free residential streets play in influencing car dependence. For this purpose, mixed-method research was conducted using literature review, a case study and a survey (n = 81) that also provided answers to the five associated sub-questions.

A car-free residential street is defined as follows: *'A residential (or mixed-use) street that does not accommodate cars and where public space is utilized for other urban features'*. This definition is modelled on similar definitions relating to the concept of "car-free''. A car-free residential street allows for a traffic-free intermediate environment providing (limited) parking separated from the street on which a residence is situated. The aforementioned definition can serve as a framework for discussing the concept of a car-free street as well as a basis on which to further develop this concept.

At the individual level of car dependency (micro), respondents perceived themselves as more car independent than car dependent on average (M = 2.84, SD = 0.69). This composite score differed significantly among respondents with or without a driver's license, the number of cars in the household and the type of car-free street. At the circumstantial level of car dependency (meso), respondents perceived themselves to be only slightly more car dependent than car dependent on average (M = 3.07, SD = 0.60). This composite score differed significantly only for respondents with or without a driver's license and the number of cars in the household. Finally, at the societal level of car dependence (macro), respondents perceive themselves on average as more car-independent than car-dependent (M = 2.42, SD = 0.71). This composite score differed significantly only among respondents with none and 1, 2 or more cars. At this level, respondents scored the lowest on average in comparison to the other two levels. No other differences were found for all three levels among the demographic and descriptive characteristics of the respondents which means that in this sample, the degree of car dependence among these factors does not differ significantly.

Statistical testing and textual analysis revealed that while the role of a car-free street does play a role in influencing car dependency, it is weak and perceived differently for each individual. Using the open-ended responses to statements 13, 14, and 15, it can be concluded that most respondents perceived that living on a car-free street does not play a role in their degree of car dependence as compared to respondents who did. In this regard, the motivations for each respondent varied widely. Precisely because of these diverse reasons given by respondents, combined with the statistical weak to moderative positive correlation, it can be concluded that for this sample, living on a car-free street does contribute to residents' perceived car dependence, but in addition to many other factors throughout the three levels of analysis as well as the extent to which an individual perceive its own car dependence.

Returning to central research question, as grounded on the conclusions presented above, this research revealed that living on a car-free street may play a role in the degree of residents' perceived car dependence. However, it is not a decisive factor and perceived car dependency is influenced by many other factors at different levels beyond the street. In addition, the precise how and the significance of car-free streets in residents' perception of car dependency depends greatly on the contextual and individual situation of a person, in which the role of living on a car-free street is perceived differently. These (sub)conclusions and thus the overall conclusion are however not representative of the population and therefore only valid within the sample taken.

Despite the limitations of this research and the fact that follow-up research has yet to reveal the extent to which these conclusions are representative of the population, this study provides a valuable baseline for further exploration of what role living in car-free streets can play in influencing residents' car dependence with the ultimate goal of reducing car dependency and improving urban livability at the streetscape level.

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