CAR-FREE LIVING AND RESIDENTIAL SATISFACTION:
A CASE STUDY OF STELLWERK 60 IN COLOGNE, GERMANY

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By

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Statement of Affirmation

I hereby declare that the master thesis submitted was in all parts exclusively prepared on my own, and that other resources or other means (including electronic media and online sources), than those explicitly referred to, have not been utilized. All implemented fragments of text, employed in a literal and/or analogous manner, have been marked as such. The translation of some sections was supported using DeepL (DeepL Translate, Deepl SE: https://www.deepl.com/translator).

Cologne, 08.07.2025 Leonie Sommer

ABSTRACT

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Car-free neighbourhoods are increasingly gaining attention as sustainable urban models, but little is known about the specific factors that influence residential satisfaction in such contexts. This study investigates how different environmental qualities are perceived, based on the '*Perceived Residential Environmental Quality Indicators'* (PREQI) and how this influence residential satisfaction. It also examines how socio-demographic characteristics and mobility experiences influence residential satisfaction. The car-free neighbourhood Stellwerk 60 in Cologne will be used as the study location. A mixed-methods design is used, combining an online survey (n = 88) with qualitative interviews with both residents (n = 13) and planning experts (n = 3) and supplemented with qualitative observations. The results show that contextual qualities such as cleanliness, tranquillity and neighbourhood atmosphere correlate most strongly with satisfaction. However, social factors such as safety and a sense of community also correlate significantly with housing satisfaction. Spatial design aspects and mobility, on the other hand, are not significantly related to satisfaction. Qualitative results show that the greatest weaknesses and factors for dissatisfaction are perceived noise pollution, the limited range of facilities for adults, and critical opinions on the greenery, total area, and apartment size, which are seen as insufficient or too small. The study highlights the importance of integrated mobility and needs-based design for different resident structures and requirements when planning successful, satisfying car-free neighbourhoods.

Keywords: *car-free neighbourhood, residential satisfaction, PREQI, mixed method, Stellwerk 60*

ZUSAMMENFASSUNG

Autofreie Quartiere gewinnen zunehmend als nachhaltige Stadtmodelle an Aufmerksamkeit, jedoch ist wenig über die spezifischen Faktoren bekannt, die die Wohnzufriedenheit in solchen Kontexten beeinflussen. Diese Studie untersucht, wie verschiedene Umweltqualitäten wahrgenommen werden, basierend auf den ‚*Perceived Residential Environmental Quality Indikatoren*' (PREQI) und wie diese die Zufriedenheit der Bewohner beeinflussen. Im Zuge dessen wird auch untersucht wie soziodemografische Merkmale und Mobilitätserfahrungen die Wohnzufriedenheit beeinflussen. Als Untersuchungsort wird die autofreie Nachbarschaft Stellwerk 60 in Köln genutzt. Es wird ein Mixed-Methods-Design verwendet, das eine Online-Befragung (n = 88) mit qualitativen Interviews, sowohl mit Bewohnern (n = 13), als auch mit Planungsexperten (n = 3) kombiniert und mit qualitativen Beobachtungen ergänzt. Die Ergebnisse zeigen, dass kontextuelle Qualitäten wie Sauberkeit, Ruhe und Nachbarschaftsatmosphäre am stärksten mit der Zufriedenheit korrelieren. Aber auch soziale Faktoren wie Sicherheit und Gemeinschaftsgefühl signifikant mit der Wohnzufriedenheit korrelieren. Räumliche Gestaltungsaspekte sowie Mobilität hingegen hängen nicht signifikant mit der Zufriedenheit zusammen. Qualitative Ergebnisse zeigen, dass die größten Schwächen und Faktoren für Unzufriedenheit die wahrgenommene Lärmbelästigung, das begrenzte Angebot an Einrichtungen für Erwachsene und kritische Meinungen zu Grünflächen, Gesamtfläche und Wohnungsgröße sind, die als unzureichend oder zu klein empfunden werden. Die Studie unterstreicht die Bedeutung einer integrierten Mobilität und einer bedarfsgerechten Gestaltung für unterschiedliche Bewohnerstrukturen und -anforderungen bei der Planung erfolgreicher, zufriedenstellender autofreier Stadtviertel.

Stichworte: *Autofreie Nachbarschaft, Bewohnerzufriedenheit, PREQI, Mixed Method, Stellwerk 60*

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Cities around the world are facing a growing number of challenges like the effects of climate change, heat islands, loss of biodiversity or air and noise pollution (Climate Copernicus, 2017; P. Kumar, 2021; UNEP, 2022). But they also deal with problems of mass motorisation, which has become more and more of a problem since the Athens Charter and the focus on car-friendly cities after the Second World War (Schlicht, 2017). As a result, the transport sector is now one of the main sources of CO_2 emissions. According to a report by the European Environment Agency (EEA), the transport sector was responsible for about 29% of the EU's greenhouse gas emissions in 2022 (EEA, 2025, Key facts, para.1). Within the transport sector, road transport is responsible for 73.2 %, the highest share of all transport-related greenhouse gas emissions in the EU in 2022 (EEA, 2024, para. 5).

Given cities' significant contribution to these problems and their need for adaptation, sustainable urban development is gaining importance (OECD, o. J.). One sustainable urban concept, which aims to drastically reduce private car traffic while simultaneously improving ecological and social factors, is the car-free city concept (Marcheschi et al., 2022; Stein, 2023). The concept of a car-free zone was first implemented in the 1960s and gained more and wider attention in the 1990s from where it was also implemented in living environments (Baehler, 2019; Dittrich & Klewe, 1996; Orski, 1972). In the last 10 years, the concept has gained again more attention in Europe with cities such as Barcelona, introducing superblocks in 2017 (Stadt Barcelona, o. J.), Ghent, implementing the largest car-free zone in Europe in 2017 (*Mobilität in Gent*, 2023), and Paris, which voted to make 500 streets car-free in 2025 (*Pariser stimmen in Bürgerbefragung für 500 Straßen ohne Autos*, o. J.).

However, while creating car-free spaces, despite the potential advantages, changes occur in the overall surrounding environment, which can have an impact on the everyday lives of residents (Marcheschi et al., 2022). In already implemented car-free neighbourhoods or superblocks, for example, urban green was added, bicycle-friendly infrastructure was created, but parking spaces were also relocated or taken away, gentrification was triggered and conflicts of use were caused (Greencity Zürich, o. J.; Pérez et al., 2025; sdg21, 2019; Stadt Freiburg, 2020). Whether car-free neighbourhoods are accepted and can achieve the desired benefits thus depends on how residents experience and evaluate the new environment (Klee & Wehnert, 2012; Salleh, 2012). For future car-free projects it is therefore important to look at the subjective perspective from the residents' point of view (Salleh, 2012). Against this

background, the concept of residential satisfaction comes into focus as it can contribute to researching subjective experiences and investigating how car-free forms of housing are perceived from the perspective of those affected (Amérigo & Aragonés, 1997; Bonaiuto, 2004; Fornara et al., 2010; Klee & Wehnert, 2012; Salleh, 2012). The influence of neighbourhoods on residential satisfaction has often been the subject of previous research (Howley et al., 2009; Romice et al., 2017). Yet, there are only a few studies that examined residential satisfaction in the specific context of permanently car-free neighbourhoods (Baehler, 2019; Höjemo, 2015; Selzer, 2021; Sommer & Weichert, 2015; Thomsen & Löfström, 2011). This could be due to the subjectivity and complexity of satisfaction, which makes the topic more difficult to grasp (Aragonés et al., 2017). In the context of car-free neighbourhoods, previous studies have tended to focus on more specific topics such as the ecological effects (Glazener et al., 2022; Nieuwenhuijsen & Khreis, 2016; Ornetzeder et al., 2008), the social effects (Hart & Parkhurst, 2011; Marcheschi et al., 2022), health effects (Glazener et al., 2022; Nieuwenhuijsen & Khreis, 2016) and changes in mobility behaviour (Baehler, 2019; Marcheschi et al., 2022; Melia, 2014). In addition, there is no uniform theoretical model for residential satisfaction, which makes it difficult to study.

This study aims to address this research gap by examining the underrepresented effects of car-free neighbourhoods on overall residential satisfaction. The study uses a framework consisting of various indicators that was developed to capture how residents perceive the quality of their neighbourhood, which in turn enables the measurement and objectification of satisfaction. This framework is called '*The Perceived residential environmental quality indicators*' and divides the indicators into four dimensions: spatial, functional, social and contextual (PREQI) (Bonaiuto et al., 2003, 2015; Fornara et al., 2010).

In order to gain a deep understanding of the residents' perspective, a case study approach was chosen for this study. The study area is 'Stellwerk 60', a car free neighbourhood in Cologne. This area was chosen because it is one of just a few permanently completely car-free residential areas in Germany. Additionally, it has been in place for about 20 years, providing a valuable basis for an in-depth study of perceived satisfaction and subjective experiences of the neighbourhood (*Stellwerk 60 - Köln*, o. J.).

Given this background, the study focuses on two central research questions:

1) *Which perceived qualities of the living environment contribute to residential satisfaction or dissatisfaction in the car-free neighbourhood Stellwerk 60?*

2) *How do the perceptions of environmental quality and residential satisfaction differ between different groups of residents in the car-free neighbourhood Stellwerk 60?*

The first question aims to examine the relationship between a car-free neighbourhood, the perception of this environment and the satisfaction of the residents. This reflects the well-established link between perceived environmental quality and residential satisfaction found in previous literature (Amérigo & Aragonés, 1997; Bonaiuto, 2004; Fornara et al., 2010), leading to the first hypothesis:

> H1: Perceived environmental quality correlates significantly with residential satisfaction.

According to the literature, perceived environmental quality is shaped by certain environmental conditions that can have either positive or negative effects. For example, noise, heat or crowds can reduce perceived quality, while green spaces and educational facilities can improve it (Steg & Groot, 2019). As a result, not all perceived qualities contribute equally to overall satisfaction (Hur & Morrow-Jones, 2008), leading to the second hypothesis:

> H2: Perceived environmental qualities (spatial, social, functional, contextual, and mobility) are associated with varying levels of satisfaction and show differential correlations with overall residential satisfaction.

In the context of car-free neighbourhoods, mobility plays an especially important role (Baehler, 2019; Nobis, 2003). Previous research could already indicate that lacking mobility can lead to a feeling of restriction (Morris et al., 2020). Therefore, it is to be expected that if residents feel restricted, that those perceived restrictions could have a negative effect and reduce residential satisfaction, leading to the third hypothesis:

> H3: Perceived mobility restrictions are negatively associated with satisfaction.

The second research question explores how socio-demographic characteristics shape the perception of environmental qualities and satisfaction. This focus is supported by previous research showing that residents' experiences can vary greatly depending on how well urban environments align with their everyday needs (Emami & Sadeghlou, 2021). Similarly, various models of residential satisfaction have incorporated socio-demographic factors (Baehler, 2019; Emami & Sadeghlou, 2021; Mohit & Raja, 2014; Tao et al., 2014). This results in a fourth and final hypothesis:

H4: Significant differences in perceived satisfaction and environmental qualities exist between resident groups.

To answer these leading research questions, the study applies a mixed methods design combining a quantitative survey with qualitative resident and expert interviews, and observations. This combination enables statistical insights and nuanced subjective perspectives simultaneously. The expert interviews further enrich the analysis with planning and policy viewpoints. The study aims to gain a differentiated understanding of the factors and needs that influence residential satisfaction in the car-free neighbourhood Stellwerk 60. This should provide valuable insights that can be used for future research and urban planning in order to successfully implement future car-free projects. If future projects understand the factors that have increased or decreased satisfaction in the past, people's general satisfaction can be increased, which can in turn increase the acceptance and sustainable success of such projects (Salleh, 2012).

The next chapter presents the theoretical background, including the current literature on the concept of car-free living and residential satisfaction, and explains the effects of car-free neighbourhoods on residential satisfaction. Chapter 3 describes and introduces the Stellwerk 60 case study area, followed by the presentation of the methodological design of the study in Chapter 4. Chapter 5 presents the results, which include both qualitative and quantitative data. The results are then discussed and interpreted in Chapter 6 and placed within the existing literature. Finally, Chapter 7 summarizes the most important results and answers the research questions.

2 Theoretical Background

This chapter provides a theoretical basis for the study by defining and outlining the relevant concepts and models. These theoretical considerations form the basis, which is needed for the subsequent case study analysis. Section 2.1 introduces the concept of car-free living, including various models such as car-free, car-reduced, and low-car neighbourhoods. Section 2.2 presents the concept of residential satisfaction, which plays a central role in this thesis. It also displays factors affecting satisfaction. Building on this, section 2.3 brings both core topics together and explores how different elements of car-free neighbourhoods may influence residential satisfaction based on literature.

2.1 Car-free living: Conceptual principles

The idea of car-free living must be understood in relation to the historical development of urban planning. Industrialisation and the Athens Charter of 1933, which suggested a strict separation of functions within the city, laid the foundations for the creation of car-focused cities (Grossmann Publicher, 1973). The reconstruction of cities after the Second World War was based on this charter and prioritised a rather car-friendly city, which enabled the rise of mass motorisation in the 1950s (Huber-Erler, 2014; Schlicht, 2017). However, this development has led to far-reaching negative effects, such as noise and air pollution, land consumption and the decline of public life and quality of urban environment (Freund & Martin, 1997; Kenworthy, 1999; Orski, 1972).

In response to those problems, various alternative urban planning models have emerged that aim to reduce the number of cars and prioritize people and sustainability (Adel & Alani, 2024). Those aims are also in line with the United Nations' Sustainable Development Goals (SDG), with Goal 11 specifically aiming to make cities inclusive, safe, resilient and sustainable (United Nations, 2015). One sustainable urban planning approach is the *car-free* concept (Nieuwenhuijsen & Khreis, 2016). The first car-free concept implemented was a car-free zone in Fort Worth, Texas in 1962 (Orski, 1972). This was followed by other car-free zones worldwide (Orski, 1972). These zones tended to be rather inner-city, commercial areas. However, in the 1990s, car-free living projects started to also aim at residential areas and people who choose to live without a car (Baehler, 2019; Dittrich & Klewe, 1996). Since then, a variety of different car-free approaches have emerged, which are listed and summarised in Table 1.

All of these approaches have in common that they aim to reduce or even prohibit car ownership and at the same time to prioritise pedestrians, cyclists and public transport (Kushner, 2005). The various approaches differ mainly in terms of whether parking or car ownership restrictions exist and whether cars are permitted within the settlement or banned completely. A primary distinction can be made between car-free and car-reduced approaches (Christ & Loose, 2001).

The term *low-car* or *car-reduced* living refers to housing estates or mixed-use developments, whereby the use and ownership of cars is only restricted but not completely prohibited. In addition, these developments also generally have fewer parking spaces than conventional

apartments and rely on off-street parking solutions and promote alternative forms of mobility such as public transport, cycling or walking (Baehler, 2019; Melia, 2014).

Table 1: Comparative overview of car-free and car-reduced neighbourhood models (own representation)

Model	Short description	Source
Car-Free Concepts		
Car-free neighbourhood	Provide a traffic free or nearly traffic free immediate environment; No or limited parking for residents (up to 0.2 parking spaces per dwelling for visitors or delivery)	Baehler, 2019, p. 19; Melia, Parkhurst, and Barton, 2010
Car-free city	'A city almost entirely free and independent from automobile as a means of transport.'	Bieda, 2016, p.56
Visually car-free	'Without cars at the surface or within the development, the parking is pooled at the edge or in underground parking garages'	Baehler, 2019, p. 19
Limited access model	Traffic-free environment, except for vehicles such as removal vans and emergency vehicles 'few parking spaces (ratios 0.15 and 0.2) intended for visitors and deliveries are close to the housing'	Melia, 2014, pp.219-220
Pedestrianised centres with residential population	Pedestrianised city centres entirely closed to through motor traffic	Melia, 2010 pp. 25–28
Low-car or car-reduced	'Residential or mixed-use developments which offer limited parking and are designed to reduce car use by residents.'	Melia, 2010, p. 223
Vauban Model	Named after the neighbourhood in Freiburg, 'Vehicles are allowed down these streets at walking pace to pick up and deliver but not to park'	Melia, 2014, p. 218

In contrast, *car-free* approaches restrict parking and car ownership completely. Therefore, the car-free city is the most radical model and bans cars altogether in the whole city (Bieda, 2016). However, there is also a milder version of car-free zones, or car-free neighbourhoods (see Table 1; Melia, Parkhurst, and Barton, 2010). These car-free zones offer no parking spaces for residents, but can provide up to 0.2 parking spaces per flat for visitors (Baehler, 2019). In addition, residents of such neighbourhoods must sign a binding declaration in which

they renounce the ownership of a car or the use of a car in their personal possession (Christ & Loose, 2001).

The definition of Baehler describes *car-free housing* as ‘new-build housing developments of any size where the residents commit to living without a private car. There is no parking for residents, but a context enabling car-free living, including infrastructures for and access to alternative mobilities (mainly bicycles, public transport and car sharing) as well as shops and services for daily needs’ (2019, p. 44). The term *car-free living* does not necessarily mean that there are no cars at all or that residents do not have their own car. It only refers to the design of the built environment which has the aim of preventing or discouraging car use (Melia, 2014). To achieve that cars become less attractive, a combination of push and pull measures are implemented. This could, for example, be an expansion of public transport services as a pull measure and a reduction in parking spaces in the city centre as a push measure (Sieber, 2021).

While both car-reduced and car-free approaches are primarily aimed at reducing private car use, they have also gained attention for their wider benefits. Car-free neighbourhoods are believed to offer additional ecological, social, and health benefits (Glazener et al., 2022; Nieuwenhuijsen & Khreis, 2016) and to improve the quality of life (Melia, 2014; Glazener et al., 2022). The perceived benefits and potential challenges of the car-free approach are discussed in more detail in Chapter 2.3.2.

However, even if the literature suggests predominantly positive effects, the implementation of such urban planning concepts can change people's familiar surroundings, e.g. through the elimination and relocation of parking spaces or through a possible change in the function of the space (Ornetzeder et al., 2008; Scheurer, 2001). Thereby changes can also be perceived as negative and threatening by residents, as Marcheschi et al found (2022). Their study has shown that higher levels of attachment can negatively influence residents' attitudes toward the implementation of car-free streets in their neighbourhood, suggesting that people may view changes in their neighbourhood as a potential threat (2022). A key question therefore is how car-free neighbourhoods are perceived by residents and how they are accepted by people who live there (Klee & Wehnert, 2012). In order to promote the acceptance of car-free environments and to achieve the long-term feasibility of such developments, it is necessary to examine car-free neighbourhoods from a subjective perspective of the residents, which is why psychological processes should be considered (Marcheschi et al., 2022; Salleh, 2012).

2.2 Residential Satisfaction and Perceived Environmental Qualities

Building on the conceptual overview of car-free neighbourhoods, this section focuses on the psychological dimension of residents' experiences of their residential environment. The following chapters address the concept of residential satisfaction, its definitions, influencing factors, and its relevance for the evaluation of car-free neighbourhoods.

2.2.1 Residential Satisfaction: Frameworks and Determinants

Residential Satisfaction (RS) is a complex and interdisciplinary concept that has been examined across various fields such as sociology (Biswas et al., 2021), (environmental-) psychology (Aragonés et al., 2017; Bonaiuto et al., 2015; Steg & Groot, 2019), urban planning (Chu et al., 2025) and architecture (Potter et al., 2001). It is derived from the general concept of satisfaction, which has various definitions (Adah & Elegba, 2015). According to some dictionaries it is defined as ‘the good feeling that you have when you have achieved something or when something that you wanted to happen does happen; something that gives you this’ (*Oxford learners Dictionaries*, o. J.), as ‘the fulfilment of one's wishes, expectations, or needs, or the pleasure derived from this’ (Oxford Dictionary, 2025) or as ‘the act of fulfilling (= achieving) a need or wish’(*Cambridge*, 2025).

Thus, RS refers to the extent to which people are satisfied with the conditions of their living environment, or more specifically, the extent to which their needs and expectations are met by that environment (Amérigo & Aragonés, 1997; Sirgy, 2021; Terzano, 2014). Although this satisfaction only relates to the one dimension of life, the living environment, it is considered to be able to also impact the overall life satisfaction (Sirgy & Cornwell, 2002). Nevertheless, it has less of an impact on overall satisfaction than other life aspects, such as health or personal relationships, where a greater influence on overall satisfaction was observed (Aragonés et al., 2017). In contrast, a mismatch between environmental qualities and personal needs can lead to stress, relocation intentions and general dissatisfaction, and should therefore be avoided (Grasser et al., 2016; Speare, 1974). That is why the assessment of residential satisfaction in urban planning is crucial (Salleh, 2012).

However, the perception of the environment and the needs can be different for everyone and is shaped by individual perceptions, lived experiences and the broader social and cultural context, which is why RS is considered a very subjective feeling (Aragonés et al., 2017). This subjectivity creates a challenge for the objective measurement and comparability of RS in different populations (Amérigo & Aragonés, 1997).

To systematically analyse residential satisfaction, researchers have developed various questionnaires and conceptual models, which all differ in their measured variables (Osama Osman, 2022). For example, Tao et al. analysed housing satisfaction with regard to socio-demographic variables, mobility characteristics, housing characteristics and preferences (Tao et al., 2014). Another model by Mohit and Raja (2014) emphasises four main dimensions that influence overall housing satisfaction: Housing characteristics and support services, Physical characteristics of the neighbourhood, social environment and socio-demographic characteristics (Mohit & Raja, 2014).

The instrument used to measure residential satisfaction in this study is presented in the next section.

2.2.2 Perceived Residential Environmental Quality Indicators (PREQI)

The framework to identify RS for this study is the *'Perceived Residential Environmental Quality Indicators'* (PREQI), an instrument developed to assess the quality of housing and the living quality that has been validated in various contexts (Fornara et al., 2010; Mao et al., 2015). The underlying assumption is that, although residential satisfaction is highly individual and multidimensional, it is nonetheless shaped by recurring environmental qualities that influence how people perceive and assess their surroundings (Fornara et al., 2010). The PREQI model represents an adaptation of the broader '*Perceived Environmental Quality Index'* (PEQI), which has its roots in environmental psychology. This tool was developed to assess subjective evaluations of different environments, such as public spaces (Bonaiuto et al., 1999; Daniel, 1976; Fernández-Ballesteros, 2003).

In contrast, the PREQI model is specifically tailored to the residential environment. It provides a cognitive-perceptual framework for analysing how individuals perceive and evaluate important environmental features. Originally, the index was based on three dimensions, namely the spatial, social and functional categories. Later studies added contextual features as a fourth dimension (Bonaiuto et al., 2003; Bonnes et al., 1997).

This four-dimensional structure, with each dimension comprising further sub-dimensions, has been empirically validated and was also further refined and presented in a shortened version proposed by Fornara et al. (2010) (Bonaiuto et al., 1999, 2003; Bonnes et al., 1997; Fornara et al., 2010). This shortened model maintains validity but at the same time improves applicability by containing fewer questions and thus simplifies surveys.

The four main dimensions contained in the PREQI model are described as follows:

- The *spatial dimension* refers to the physical features of the neighbourhood, including the perception of architectural and urban design, spatial organisation, accessibility and the availability and quality of green spaces (Fornara et al., 2010).
- The *social dimension* includes all social experiences and interactions, perceived sociability, sense of security, and discretion (Fornara et al., 2010).
- The *functional dimension* relates to the perception of functional resources available within the neighbourhood, including welfare services such as healthcare and schools, recreational and commercial facilities, as well as transport infrastructure (Fornara et al., 2010).
- The *contextual dimension* includes lifestyle-related factors such as the perceived pace of life, atmosphere and quality of life, as well as environmental health and the general level of maintenance and care in the area (Fornara et al., 2010).

In addition to these four dimensions, the index also includes neighbourhood attachment (Amérigo & Aragonés, 1997; Bonaiuto, 2004; Fornara et al., 2010). Other environmental psychology literature confirms that neighbourhood attachment has an influence on people's behaviour and well-being (Lewicka, 2011; Scannell & Gifford, 2017).

PREQI has already been used in multiple studies to investigate the influence of an environment on perceived life satisfaction. For example, a study by Zhou (2021) used the PREQI model to investigate the effects of urban Chinese environments. The study came to the conclusion that different dimensions have a strong effect on residential satisfaction and that the satisfaction of people living in the urban environment differs greatly from that in a rural environment (Zhou et al., 2021). Another study by Mao et al. (2015) also examined the PREQIs in the context of Chinese neighbourhoods. The results showed that the contextual dimension such as environmental health and care were strongly related to residential satisfaction and neighbourhood attachment (Mao et al., 2015). Moreover, Bonaiuto et al, (2006) applied and tested the PREQIs in an Italian city. The study showed that the PREQI model and the Neighbourhood Attachment indicator accurately reflect how residents perceive the environmental quality of their neighbourhoods, while capturing the diverse, context-specific characteristics of different urban areas (Bonaiuto et al., 2006).

Overall, the PREQI model provides a good opportunity to investigate the satisfaction of residents in their specific living environments and to gain a detailed understanding of how

residents perceive the environmental qualities of car-free neighbourhoods in particular. The different dimensions help to identify specific factors that contribute to residential satisfaction or dissatisfaction and to assess how innovative planning concepts are received by those who experience them in everyday life.

2.3 The influence of (car-free) neighbourhoods on PREQI and residential satisfaction

This chapter integrates the two central concepts of the previous sections. It examines the literature on how residents perceive the specific characteristics of car-free neighbourhoods and how these shape their level of satisfaction. Based on an analysis of the current empirical literature, the chapter outlines both the potential benefits and limitations of car-free neighbourhoods with regard to residential satisfaction. It also identifies existing research gaps and presents the analytical framework for the subsequent case study.

2.3.1 Overall Residential Satisfaction in Car Free neighbourhood

The relationship between satisfaction and the residential environment has received considerable attention (Aragonés et al., 2017; Balestra & Sultan, 2013; Chu et al., 2025; Emami & Sadeghlou, 2021; Hur & Morrow-Jones, 2008). However, only few scientific studies have explicitly dealt with satisfaction in a car-free environment (Baehler, 2019; Höjemo, 2015; Selzer, 2021; Sommer & Weichert, 2015; Thomsen & Löfström, 2011).

Studies that have addressed this issue include e.g. those by Sommer and Weichert, who investigated the car-free neighbourhood in Freiburg. Their study identified high levels of satisfaction among residents of the car-free Vauban district (Sommer & Weichert, 2015). Similarly, a study by Baehler (2019), who examined nine different car-free areas in Germany and Switzerland, observed generally high levels of satisfaction and positive attitudes toward a car-free neighbourhood among residents. However, the study focus is on mobility practices and further indicated that car-free neighbourhoods are dependent on certain mobility infrastructure and services to function and thus to achieve this satisfaction. This includes, for example, a built environment that allows people to get around on foot or by bike, or the availability of nearby and reliable public transportation (Baehler, 2019).

Another study by Höjemo aimed to identify key success factors and challenges in European car-free neighbourhoods. The study indicated that certain factors contribute significantly to satisfaction in car-free neighbourhoods, such as child-friendly outdoor spaces, proximity to

green spaces and good connections to alternative forms of mobility. At the same time, challenges such as alternative transport options and social scepticism are mentioned as limitations to residential satisfaction. However, no statement was made on overall satisfaction (Höjemo, 2015).

There are other studies that do not directly address car-free neighbourhoods but can still contribute to the topic. Other previous studies have, for example, examined the effects of short-term car-free street experiments (Marcheschi et al., 2022). Although the research was not conducted in fully implemented car-free neighbourhoods, the findings still highlight the positive impact of car-free settings on both perceived environmental quality and emotional attachment to place. Moreover, März et al., investigated how streets can be made more liveable. The results suggested banning cars and implementing urban green (März et al., 2022). From this it can be suggested that car-free settlements have the potential to be more liveable.

Since the current state of literature on general resident satisfaction is rather low, the next chapter takes a closer look at the individual aspects of car-free neighbourhoods, to gain a deeper understanding of how they can affect residential satisfaction as well as which advantages and disadvantages such neighbourhoods offer.

2.3.2 The impact of Car-Free Neighbourhoods on PREQIs

The following sections provide an overview of the positive and negative impacts of car-free neighbourhoods. For enhanced internal coherence, the aspects are structured based on the PREQI dimensions (spatial, social, functional, and contextual), as well as Mobility. This dimension is added as a separate category, as it plays a decisive role in the context of car-free living.

2.3.2.1 Mobility

Mobility is one of the most studied aspects in research on car-free neighbourhoods, as it is one of the factors most directly affected by the implementation of such urban developments, due to the change in the use of the private car, especially considering that in most urban areas the private car still dominates daily transport behaviour (Baehler, 2019; Marcheschi et al., 2022; Melia, 2014). As a result, car-free neighbourhoods can change habits of residents that require an adjustment in behaviour, which can be challenging (Verplanken & Orbell, 2022). Mobility changes therefore require more in-depth consideration.

The removal of the private car is seen as a good opportunity to shift the main mode of transport towards a more active one such as walking or cycling, which is associated with positive effects, such as health benefits, e.g. a lower risk of chronic diseases (Melia, 2014; Nieuwenhuijsen & Khreis, 2016), or the promotion of mental well-being (Scrivano et al., 2024). Even if the switch to more active modes of transport is generally independent of a car-free concept, this concept can help to promote the modal shift to a more active but also sustainable behaviour, as it inevitably pushes people to other modes of transport by eliminating the car and, in turn, pulls the active forms of mobility by offering suitable infrastructures, such as bike lanes, pedestrian-friendly design (Nieuwenhuijsen & Khreis, 2016). Cycling is seen as a basic mode of transportation in car-free neighbourhoods, which is why residents of car-free neighbourhoods tend to be better equipped with bicycles compared to the entire city in which they live as Baehler observed (2019).

However, the absence of private cars may also impose mobility constraints. Morris et al (2020) noted that limited access to a car can reduce participation in social and leisure activities and affect quality of life negatively. This can pose a particular challenge for individuals with mobility impairments, such as older adults or people with disabilities who may find it difficult to use alternative modes of transport (Scheurer, 2001). To avoid such negative effects, car-free districts should offer good alternatives to the car, e.g. good cycling infrastructure, shared mobility services and accessible public transport, which all need to meet the demand (Baehler, 2019; Sommer & Weichert, 2015).

Another challenge is the regulation of vehicle access. In Vauban, for example, residents reported frustration and even dissatisfaction with parking violations and inadequate control mechanisms (Scheurer, 2001). Frustration was particularly high among car-free households, who reported that some car owners are circumventing the regulations by parking on designated car-free streets, undermining the intended character of the neighbourhood. There are also residents who circumvent the regulations by registering vehicles under different names and parking in neighbouring areas, causing frustration for neighbouring residents (Scheurer, 2001). Moreover, the main obstacles to ensuring a satisfactory alternative mobility without cars include a lack of good alternative and time-saving transport options, particularly outside urban areas and outside business hours, as well as the lack of the reliability of public transport (Tori et al., 2025).

In summary, mobility in car-free neighbourhoods brings both advantages and challenges. However, integrated and reliable multi-modular mobility is needed in order not to restrict individuals and to provide suitable alternatives to the car for all needs and distances.

2.3.2.2 Spatial Qualities

The spatial aspects are also influenced by a car-free design, as a lot of space in cities is normally taken up by traffic (European Commission, 2021). For example, in Cologne, the proportion of space covered by roads is 16.3% (Statista, 2022). Furthermore, cars generally consume by far the largest amount of space, while pedestrians and cyclists are the most space efficient. A car traveling at 50 km/h consumes approximately 140 m² of space, but even when stationary, it still consumes 13.5 m². Pedestrians, on the other hand, consume less than 1 m², and public transport vehicles that are occupied at a maximum of 40% consume only up to a maximum of 9 m² (Martin, 2014).

Car-free environments therefore have the potential to free up a lot of space that can be used for other purposes that focus more on people and sustainability (Blechschmidt, 2016; Croeser et al., 2022). In practice, the vacated spaces in car-free neighbourhoods are often converted e.g. into community spaces, community gardens or pedestrian-friendly streets, as shown by existing car-free neighbourhoods such as GWL in Amsterdam, Greencity in Zurich, Vauban in Freiburg or Culdesac Tempe in the US-Arizona (Culdesac, 2025; Greencity Zürich, o. J.; sdg21, 2019; Stadt Freiburg, 2020).

When comparing these neighbourhoods, it is particularly noticeable that they all pursue the goal of increasing green spaces, which has several advantages. Firstly, urban greenery has many ecological advantages such as improving biodiversity and air quality, or counteracting urban heat through evaporation and shadows (Haq, 2011). But they are also associated with benefits like improving relaxation and recreation, improving well-being and satisfaction or aesthetics (Haq, 2011). Thus, the efficient use of space reclaimed from traffic can not only enhance ecological benefits but can also positively impact residents' overall health and quality of life (Haq, 2011; Nieuwenhuijsen, 2021). However, potential conflicts of use can also arise during the redesign of the area, as residents may have different needs and user preferences (Aragonés et al., 2017). Thus, its effect on satisfaction may depend on how the potentially free space is used and how it is perceived by the residents.

Moreover, the spatial dimension can also have a direct influence on satisfaction, as aspects such as perceived aesthetics, architectural design, size and layout of apartments or the

aesthetics of the neighbourhood can also influence how residents perceive their living environment and affect residential satisfaction (Fornara et al., 2010). A study by Naumann and Nadler (2023) indicates that architectural features, dwelling size, neighbourhood appearance, apartment sizes and the availability and quality of public open spaces are key elements shaping perceptions of urban living and residential satisfaction (Naumann and Nadler, 2023). However, these aspects are very subjective and may also differ greatly between residents.

Furthermore, the spatial dimension includes the connection and perception of the location of the neighbourhood (Fornara et al., 2010). In car-free neighbourhoods, it is particularly important that residents can manage their everyday lives without their own car, which is why the location and accessibility are particularly important there (Blechschmidt, 2016; Christ & Loose, 2001). However, it is difficult to generalize, as the idea of a ‘good’ location varies from person to person and the context of each car-free neighbourhood can differ considerably.

In summary, car-free districts can have a positive influence on spatial design, but the impact on satisfaction depends mainly on how the free space is used, how the area is designed and if the needs of residents are met.

2.3.2.3 Social qualities

Social qualities play an important role in shaping the quality of life in neighbourhoods, influencing residents' sense of community, social interactions and general well-being, and can be influenced by the design of the environment (Alnaim et al., 2025). There are several studies which show that more walkable and pedestrian-oriented neighbourhoods provide more opportunities for human interaction (Nieuwenhuijsen & Khreis, 2016; Rogers et al., 2025; Wright, 2005). In addition, Leyden (2003) indicates that residents in walkable neighbourhoods tend to have a higher level of social capital, are more likely to know and trust their neighbours, and are socially engaged (Leyden, 2003). Even if ‘walkable’ is not synonymous with ‘car-free’, car-free neighbourhoods, as already mentioned, often offer a pedestrian-friendly environment that pulls walking (Baehler, 2019).

These results are confirmed by other studies that suggest that residents of car-free or low-traffic neighbourhoods tend to have more social contacts and stronger relationships within their immediate surroundings than those living in conventional areas (Hart & Parkhurst, 2011; Marcheschi et al., 2022). In addition, a study, conducted in a car-free project in Vienna, found that residents had more friends in the neighbourhood and recognized more people by sight

(Ornetzeder et al., 2008). Also, the residents showed a high level of community involvement and organised events such as courtyard parties and flea markets (Ornetzeder et al., 2008).

Marcheschi et al. (2022) could show that car-free streets promoted spontaneous encounters and social interactions. In addition, their study showed that residents rated places that promote social interaction much more positively and that such places are crucial for improving the acceptance and success of car-free projects (Marcheschi et al., 2022).

On the other hand, car dependence can contribute to exclusion, particularly among groups who cannot or do not want to drive, such as children, the elderly, people with disabilities, or low-income households (Lucas, 2012; Schwanen et al., 2015). By reducing the dominance of private car use, car-free neighbourhoods may thus offer a more equitable, social inclusive urban environment. But at the same time there is also the fear that the population structure of such neighbourhoods can attract similar people and lead to a homogeneous population, which could limit social diversity in the neighbourhood (Melia, 2014).

Based on the above literature, car-free neighbourhoods seem to offer infrastructure that have the potential to promote a positive social structure and a sense of community. However, most studies show that the most important promoting aspect is the walkability of a neighbourhood, which is not necessarily the same as the car-free concept.

2.3.2.4 Functional Qualities

Functional aspects such as access to services, commercial infrastructure and leisure facilities are also essential components of residential satisfaction, as noted in the PREQI concept (Fornara et al., 2010). For residents to have a high level of satisfaction, it is important that residents are able to meet their everyday needs within the neighbourhood (Aragones, 2017; Fornara et al., 2010). However, comparatively little attention has been paid to this topic in the specific context of car-free residential areas, but rather in connection with concepts such as the 15-minute city. This concept is another sustainable urban concept that aims to ensure that all important functions such as housing, work, doctors, schools, etc. can be reached on foot or by bike within 15 minutes (Krauze-Maślankowska & Maślankowski, 2025).

Studies referring to the 15-minute city have found that residents generally consider it important that functionalities such as grocery stores and healthcare facilities are close to where they live (Guzman et al, 2024; Verma et a., 2025). In line with these findings, Naumann and Nadler (2023) highlighted the importance of mixed zoning and easy access to daily services as key success factors for residential satisfaction in newly developed urban

neighbourhoods (Naumann and Nadler, 2023). In addition, Verma et al. showed that nearby shops significantly increase the likelihood of shopping trips being undertaken on foot (Verma et al., 2025). This suggests that it is very important for a car-free neighbourhood to have shops nearby so as not to be dependent on the car. However, Verma also notes that proximity to shops can play a different role if it is possible to order online and have it delivered (2025).

The literature suggests that in general, regardless of whether a neighbourhood is car-free, it is important to have necessary utilities nearby and that the closer people live to stores, the more likely they are to walk and the less reliant they are on a car. However, how the presence of stores and the respective distances affect satisfaction in car-free neighbourhoods remains unclear.

2.3.2.5 Contextual Qualities

Contextual qualities refer to the aspects of air and noise pollution, the general pace of life, and the perceived atmosphere of a neighbourhood, which can have an influence on satisfaction (Fornara et al., 2010).

Especially noise and air pollution are major environmental problems in cities around the world (Rey-Gozalo et al., 2023; Sicard et al., 2023). In the EU, road traffic is the biggest contributor to noise pollution (EEA-Noise, 2025; Münzel et al., 202). Numerous studies could show that noise pollution and poor air quality can negatively affect satisfaction and even contribute to health problems (Hur & Morrow-Jones, 2008; Khomenko et al., 2021; Muhammad Anees et al., 2017). For example, long-term exposure to noise produces a variety of health effects including annoyance, mental health, hearing system, negative pregnancy outcomes and cognitive impairment in children, sleep disturbance, and negative effects on the cardiovascular and metabolic system, potentially leading to premature death (WHO, 2018).

Naumann and Nadler (2023) indicated a significant correlation between perceived noise and satisfaction. However, there are very few studies on noise pollution specifically in car-free residential areas. In a systematic review by Glazener et al. (2022) only one study was found that examined noise levels in relation to car-free days, indicating a clear research gap. According to Glazner et al., the results of the noise pollution study showed that they indicated a moderate noise level on regular days and a slight reduction in noise level on car-free days (Glazener et al., 2022). Additionally, in Paris, the volume was measured on a car-free day experiment in the city centre, and it was found that the sound level dropped by half (Willsher, 2015).

In contrast, another study accompanied a project in Dortmund that aimed to redesign a particular street to make it more liveable. The study found that residents feared a significant increase in noise pollution. This increase in noise was later confirmed when the redesigned area was used intensively, both during the day and at night (März et al., 2022). This result indicates that car-free or liveable neighbourhoods do not necessarily mean quiet neighbourhoods.

Research on air quality in car-free settings is comparatively well established. For example, a one-day car-free street experiment in Paris showed that nitrogen dioxide levels in parts of the city fell by up to 40 % (Willsher, 2015, para. 2). In addition, residents of car-free areas tend to have a lower carbon footprint, often well below the national average, as they are less reliant on motorised transport (Melia, 2014). Such reductions are directly linked to positive health effects, as exposure to air pollution is associated with an increased risk of respiratory and cardiovascular diseases (RCEP, 2007).

In summary, the avoidance of traffic in car-free neighbourhoods has the potential to avoid air and noise pollution and thus contribute to positive and health-promoting effects. However, there are also indications that the elimination of the traffic noise source could create other new sources of noise. Further research is needed to better understand noise levels and perceived stress in car-free neighbourhoods including its impact on satisfaction.

2.3.3 Additional Influences on Residential Satisfaction

In general, socio-demographic factors determine people's needs and influence how the available resources for meeting these needs are perceived (Aragonés et al., 2017). It was found that individual characteristics such as socio-demographic factors can significantly influence how people evaluate their living environment (Baehler, 2019; Emami & Sadeghlou, 2021; Mohit & Raja, 2014; Tao et al., 2014). Mridha (2020), for example, found a significant relationship between residential satisfaction and age, gender, and marital status (Mridha, 2020).

Regardless of car-free neighbourhoods, it is important to meet the needs of all people, but especially those with more limitations who are at particular risk of being excluded, such as the elderly, as still often happens in urban planning (Chan et al., 2023; Hammond et al., 2024; Phillipson & Grenier, 2021). This phenomenon of exclusion, also known as ageism, can pose a significant threat to the wellbeing of older adults (Kang & Kim, 2022). In order to plan car-

free neighbourhoods satisfactorily for older and other vulnerable groups, it is important to address their needs and fully take them into account in the planning process.

In regard to household types, families make up a high proportion of the residents within a car-free neighbourhood (Baehler, 2019; Scheurer, 2001). Interviews by Baehler showed that many parents perceive car-free environments as an ideal setting for raising children, which in turn enhances their own residential satisfaction according to their own statement (Baehler, 2019). In contrast, conventional urban environments are associated with a less child-friendly environment, as the dominance of cars can hinder safe outdoor play (Bartlett, 2002; Lopes et al., 2014). In general, the acceptance of car-free concepts seems to be higher among younger, environmentally conscious residents and lower among elderly or people with a more car-dependent lifestyle (Baehler, 2019; Melia, 2014).

In summary, socio-demographic factors shape residents' perceptions of their living environment, with particular attention being paid to vulnerable groups. Car-free neighbourhoods tend to attract families and younger, environmentally conscious residents, which underscores the need for inclusive planning.

2.3.4 Linking the determinants influencing residential satisfaction in car-free Neighbourhoods

Based on the theoretical foundations outlined in the previous sections, this study develops a conceptual framework that summarizes the key determinants of residential satisfaction in car-free neighbourhoods.

As already mentioned, the model is based on the shortened version of the PREQI model proposed by Fornara et al. (2010), which divides the environmental quality into four dimensions. For this study, the dimension of mobility is added to the framework as a separate dimension. The reason for this is to take better account of the specific conditions of a car-free neighbourhood design as already expressed in the previous chapter of mobility (2.3.2.1). In this framework, mobility refers to residents' perceptions of the quality, accessibility and integration of alternative transportation options, including pedestrian friendliness, cycling infrastructure, access to public transport and shared mobility services (e.g. car sharing and the mobility station). In addition, the model adds the variable of socio-demographic characteristics as those characteristics can also have an impact on the perception of the environment and thus also on the residential satisfaction level, as stated in the previous chapter (see chapter 2.3.3).

The resulting theoretical framework for this thesis (see Figure 1) illustrates the relationship between car-free neighbourhoods and residents' perceived satisfaction. As already explained in the literature, this relationship is explained by several determinants that may be perceived differently in a car-free design than in other places, and this perception in turn shapes the residential satisfaction. It is assumed that the different determinants can have a direct influence on satisfaction, while the socio-demographic factors play a moderating role.

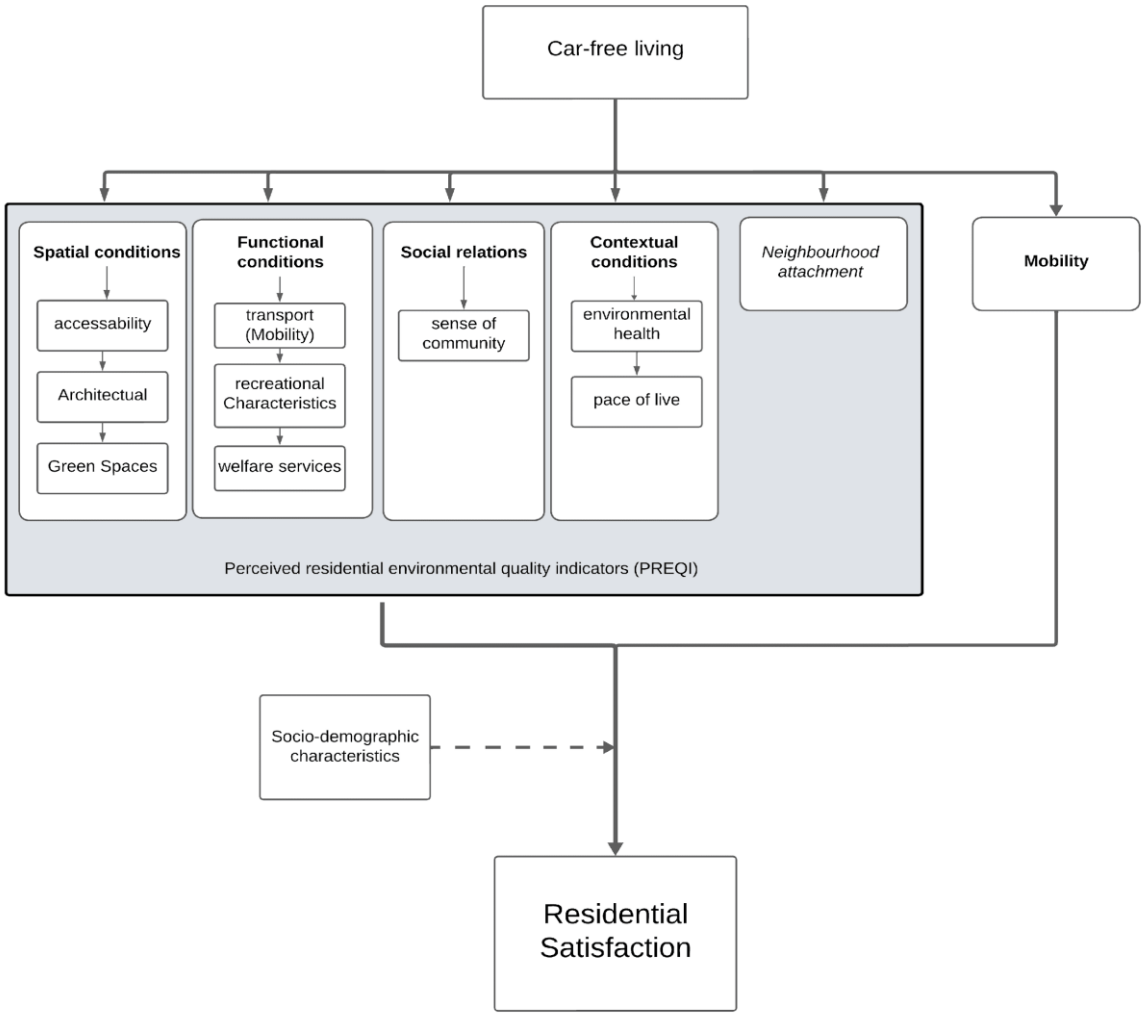

Figure 1: Conceptual Framework- determinants of residential satisfaction in car-free Neighbourhood (own representation based on the PREQI model by Fornara et al. 2010)

3 Case-Study Area: Stellwerk 60

This chapter provides a detailed introduction to the case study area selected for this study and gives a brief explanation of why this particular case study area was chosen.

The case study chosen for this study is the car-free neighbourhood *Stellwerk 60* in Cologne Germany (Köln, o. J.). It is located in the north of the city centre in the district Cologne-Nippes, directly next to the railway line between the stops: 'Köln-Nippes' and 'Köln Bilderstöckchen Geldernstr. /Parkgürtel'. There, it is built on the site of a former railway maintenance depot. Figure 2 offers a visualization of the neighbourhood within its surrounding area as well as a floor plan of the area.

Figure 2: Visualisation of the car-free Stellwerk 60 neighbourhood, on the left as a map and on the right as an aerial photograph (Sources are left: Nachbarn60 and right: vermessung.rls-Stellwerk 60)

The project began in 1994 with the initial idea of an initiative of a citizens' movement, which then founded a working group (*'Car-free cologne').* This Group consisted of around 100 Cologne residents. The settlement was then realized and completed between 2005 and 2013 (*Stellwerk 60 - Köln*, o. J.).

To realize the project, many different parties were involved, like BPD Immobilienentwicklungs GmbH, the architectural firm Schneider-Sedlaczek, GAG Immobilien AG, the City of Cologne, the Wuppertal Institute for Climate, Environment and Energy, and Naturstrom, as well as the neighbourhood association Nachbarn60 e.V. („MobiQ", o. J.).

The Neighbourhood covers an area of 4 hectares and includes a total of 430 residential units, which provide a home to around 1500 residents (*Stellwerk 60 - Köln*, o. J.). The development is based on a mix of different house types. There are 72 detached houses in total, the rest are apartments. 83 % of these are rental apartments. There is also a multi-generational house and a few senior-friendly apartments as well as social housing units („MobiQ“, o. J.). In total, the public green spaces, which mainly consist of a large green area and several inner courtyards, cover an area of around 18,600 m² (*Stellwerk 60 - Köln*, o. J.). 80% of the residents are families as one study, has measured (Baehler, 2019). However, there is no official data on general socio-demographic information.

The case study area of Stellwerk 60 in Cologne exemplifies a specific subtype of car-free development, namely the *limited access model* (see chapter 2.1). Such concepts limit parking spaces and shift them outwards and prohibit cars from entering the settlement, but allow entry in exceptional cases (e.g., in emergencies, deliveries, or removals). The car traffic is primarily restricted through spatial design measures such as bollards, narrowed road sections (Baehler, 2019; Melia, 2014). In Stellwerk 60, there are also such measurements as well as limited parking spaces. The ratio is 0.2 and thus meets the criteria for a car-free neighbourhood according to Melia, Parkhurst, and Barton (2010) („MobiQ“, o. J.).

The existing parking spaces are located in a neighbourhood garage on the edge of the neighbourhood. 80 parking spaces are available to residents with their own cars, 30 spaces are reserved exclusively for visitors, and ten additional spaces are available for car sharing vehicles („MobiQ“, o. J.). There are also additional car sharing stations with a total of 20 vehicles on the other side of the neighbourhood. Electric cargo bikes are also available for communal use. Each building has a mobility station and bicycle garages. The city center is about 2.5 km away by bike. Trams, S-Bahn trains, and buses also stop near the development, providing connections to the rest of the city („MobiQ“, o. J.).

In addition to mobility, the neighbourhood also provides a social infrastructure. A common room, the so-called ‘Kaffee-Kessel’ and various working groups are intended to facilitate neighbourly exchange. In addition, the neighbourhood association Nachbarn60 e.V. organizes events and projects in the Stellwerk 60 neighbourhood („MobiQ“, o. J.). There is also the so-called ‘*Handwerkerinnenhaus’ (*Craftswomen's House) on the edge of the neighbourhood. This is intended to provide a space for creative and craft activities (*Handwerkerinnenhaus Köln e.V. – Lern- und Bildungsort für Mädchen und Frauen*, o. J.).

Overall, this neighbourhood was chosen as a case study because, on the one hand, it is one of the few completely car-free residential areas in Germany. The often-mentioned Vauban neighbourhood in Freiburg, for example, is not completely car-free but rather car-reduced and only limits the available parking spaces (Freiburg, n.d.). On the other hand, with its almost 20 years of existence, Stellwerk 60 offers sufficient everyday experiences of the residents to provide valuable insights into the effects of car-free living. The diverse established facilities, such as the mobile station and the neighbourhood association, also offer diverse research opportunities.

4 Methodology

This chapter outlines the methodological approach adopted to address the research questions and test the associated hypotheses. It begins with an overview of the research design (4.1), followed by a detailed explanation of the data collection process and the instruments used (4.2). The subsequent section describes the procedures for data analysis (4.3), and the chapter concludes with a discussion of quality criteria, including reliability, validity, and ethical considerations (4.4).

4.1 Research Design

This chapter outlines the overall research design of the study. It presents the methodological approach taken to address the research objectives and respond to the central research questions. The objective of the research is to explore how residents perceive car-free neighbourhoods, with a particular focus on factors influencing residential satisfaction. To achieve this, the study investigates the interplay of social, spatial, and mobility-related aspects within a specific case study of Stellwerk 60. The case study approach was chosen because a real-life example such as Stellwerk 60 offers the opportunity to observe processes, interactions and the dynamics of the actors in their natural environment and to generate in-depth, relevant data (Krusenvik, 2016). In addition, case studies offer concrete, application-oriented findings that can be relevant and transferable for planning practice, policy advice and future neighbourhood development, even if they cannot be generalised in a statistical sense (Flyvbjerg, 2006; Gomm et al., 2009).

Methodologically, the research is based on a mixed methods approach, integrating both quantitative and qualitative data to develop a comprehensive and nuanced understanding of residential satisfaction and perceived environmental quality in the car-free neighbourhood

Stellwerk 60. Specifically, this study applies a Convergent Parallel Mixed-Method Design by using different quantitative and qualitative methods in parallel, analysing them separately and later integrating them to compare, validate and contextualize the results. This ensures that the research question is viewed from a wide range of perspectives, providing a holistic insight into the experiences of residents and how the neighbourhood functions (Ahmed et al., 2024; Creswell & Clark, 2011; Dawadi et al., 2021; Doyle et al., 2016). This mixed methods design is particularly appropriate for case study research, as it allows for flexibility, depth, breadth, and supports a multi-dimensional exploration of complex urban environments (J.Mills et al., 2010).

The research design consists of four different methodological approaches, including a quantitative survey, qualitative interviews with experts and residents, and qualitative observations, which will be described in more detail in the next chapter on data collection (4.2). The overall concept of research is shown schematically in Figure 3.

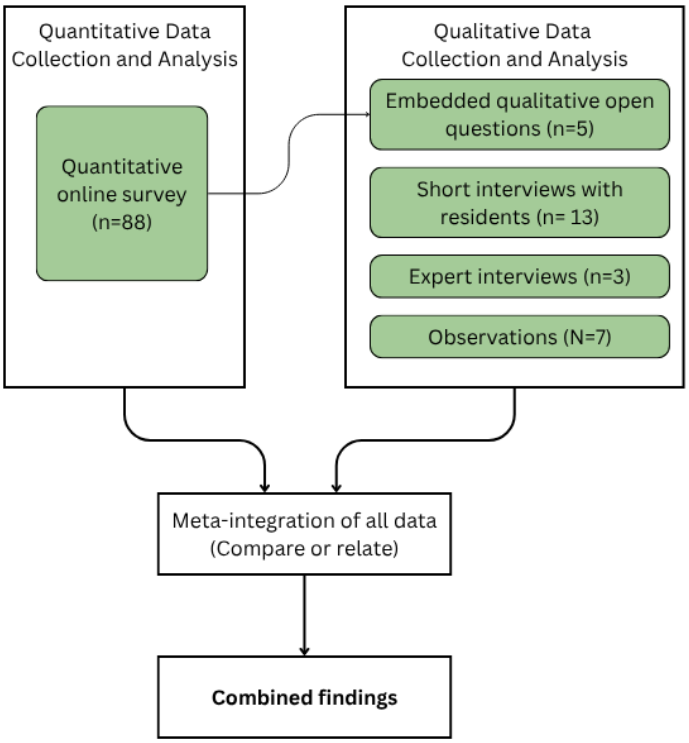

Figure 3: Research design of the convergent mixed Method used for this study

4.2 Data Collection

Due to the mixed methods approach, various data collection methods were used, which are described separately below. The online survey is explained first (4.2.1), followed by a description of the qualitative methods of observation (4.2.2), interviews with residents (4.2.3) and expert interviews (4.2.4).

4.2.1 Quantitative Online Survey

The quantitative survey was conducted to collect standardized and comparable data on residential satisfaction and perceived environmental quality. It enables statistical evaluations of correlations and differences between different groups of residents and allows the identification of significance (Kotronoulas et al., 2023). The target group for the survey were residents of the case study area Stellwerk 60, which has been described in chapter 3. For the sample, primarily residents of the neighbourhood were considered, as well as people from the surrounding area who frequently spent time in the car-free zone. In order to identify possible biases, the questionnaire explicitly recorded whether the participants live directly in the neighbourhood or only spend time there frequently. According to their own statements, only actual residents took part.

In total, 88 residents responded to the survey. Participants' demographics revealed a predominance of families (58%), followed by couples (22%), singles (17%), and flat-sharing communities (2%). The participants had lived in the neighbourhood for an average of 8 years, and all participants stated that they had lived there for at least one year. This ensures that most respondents are familiar with the neighbourhood and have enough experience to make an informed assessment of the quality of environment. The average age of respondents was 51 years (SD = 14.34), with ages ranging from 12 to 79 years. Regarding income, 23.9% reported earnings between €3,000 and €4,000, while 36.4% had higher incomes, 36.4% lower, and 3.4% did not disclose their income. In terms of educational background, the largest proportion (66%) of participants had a university degree[1].

The quantitative survey was conducted between [18.12.2024] and [20.01.2025] and was created using the online programme SoSci Survey. To ensure broad participation among residents, an invitation flyer containing the survey link was distributed to all households via letterboxes in December (see appendix 6). Additionally, the link was shared through the

[1] Due to an error, the socio-demographic characteristics of gender and nationality were not included in the quantitative survey. This represents a limitation with regard to the analysis of socio-demographic differences.

neighbourhood association's email distribution list and published on the Stellwerk 60 residents' association website.

The survey (see appendix 1 for the complete questionnaire document) was administered online and comprised three distinct categories of questions:

1. **Closed-ended questions**, based on a 5-point Likert scale, allowing residents to self-assess their level of agreement or satisfaction with various relevant measurement items.
2. **Multiple-choice questions** to capture specific preferences and behaviours.
3. **Open-ended questions** (OEQ)[2] aimed at gaining deeper qualitative insights into specific topics, such as suggested improvements or personal experiences. In addition, there was always an option to openly enter a missing answer option under 'other' for all multiple-choice questions, thereby reducing potential response bias.

The closed-ended questions were based on indices measuring perceived environmental quality, a validated instrument designed to assess residents' satisfaction with their living environment. Specifically, the shortened version of the Perceived Residential Environmental Quality Indicators (PREQIs) by Fornara et al. (2010) was utilised. The original questionnaire contains 19 scales with a total of 62 question items. The items by Fornara were structured using a 5-point Likert-type scale. For the present study, questions from all four Scales were selected, focusing solely on those relevant to the case study context of a car free neighbourhood. This approach was adopted to minimise the length of the questionnaire and thus maximise response rates and to better capture the specificities of a car-free neighbourhood, which is a methodically accepted approach (Boateng et al., 2018).

Additionally, some items were adapted to better reflect the specific characteristics of the Stellwerk 60 neighbourhood. Furthermore, self-assessment questions on life satisfaction, well-being, and social satisfaction were incorporated to enable statistical analysis of the relationship between perceived environmental quality and perceived residential satisfaction. In total, the survey included 53 questions, distributed across the following categories:

- Architectural/Urban Planning Features Scale (11 questions)
- Socio-relational Features Scale (8 questions)

[2] In the following, the data from the open questions are abbreviated as OEQ and the respective participant number is given as follows (OEQ-PX).

- Functional Features Scale (16 questions)
- Context Features Scale (5 questions)
- Improvement and risk assessment (3 questions)
- Satisfaction and well-being (9 questions)
- Neighbourhood attachment (one question)

Additionally, the survey included some questions on socio demographic data as well as duration of living, main motivation for the move and car ownership. The complete questionnaire is provided in appendix 1.

To assess the overall perception of each dimension aggregated indexes have been calculated. The *mobility Index* was calculated based on 10 Items (8 different questions on traffic situations (MO01_01- MO01_08), one question on car sharing (MO03) and general mobility well-being (MO08)). To assess the internal consistency of the mobility index, Cronbach's Alpha was calculated. The result ($\alpha = 0.85$) indicates a high level of reliability, suggesting that the selected items measure a coherent construct related to perceived mobility qualities.

The *spatial index* consists of 3 variables. The calculated Cronbach's alpha of 0.76 indicates good internal consistency among the three items, suggesting that they reliably measure the same underlying construct.

The *social index* was created based on four items: sense of community (SO01), perceived ease of getting to know others (SO04), social satisfaction (SO06) and perceived safety (SO05). The item 'perceived ease of building social ties compared to other neighbourhoods' (SO08) was excluded from the index, as it was not based on a Likert scale. The calculated Cronbach's alpha of 0.8 for the Social Index indicates a good internal consistency of the four items.

The *functional index* consists of seven items (FU01_01- FU01_07). The calculated Cronbach's alpha of 0.65 suggests an acceptable internal consistency of the index.

The *context index* was created based on four items: perceived neighbourhood atmosphere, residents' care for the well-being of their neighbourhood, peace and quiet, and neighbourhood cleanliness (AT01_01- AT01_04. The resulting Cronbach's alpha of 0.87 indicates a high internal consistency of the five items, suggesting that they reliably measure the underlying construct of contextual environmental qualities.

4.2.2 Qualitative Observations

In addition to the quantitative resident survey, systematic observations were also carried out to enable interview statements to be verified or supplemented by objective impressions on site. Observation notes can help with the interpretation of statements, especially in the case of ambivalences or contradictions that can arise through mixed methods (Flick, 2014). The observations took place in the period from [16.10.2014] to [04.04.2025] and provided additional information about the actual use of the residential environment and in order to support the interpretation of the survey and interview data. The following aspects were particularly considered and documented during the observations:

a) Use of public spaces in the neighbourhood.
b) Where people spend time, how long and what they do.
c) Interactions between residents in communal areas: whether encounters take place, where they take place and for how long.
d) Perceptible effects of car-free design on daily life.
e) Perceptible environmental qualities: noise level, quality of green space, aesthetics
f) Perceptible satisfaction: do people seem happy, do they laugh, do they seem stressed?

In order to reduce distortions of weather and time of day, the observations were carried out on different days of the week, at different times and in different weather conditions. However, only days were selected when the weather made it possible to spend time outdoors. The following table 2 shows the dates and times when observations were made. In general, however, this method has only been seen as a supplement and does not constitute the main methodology.

Table 2: Dates and duration of the observations

Date of observation	Duration of observation
04.04.2025 (Friday)	16:55 – 18:17
23.02.2025 (Sunday)	13:35 – 14:00
21.02.2025 (Friday)	14:00- 14:40
12.02.2025 (Wednesday)	10:30 -11:00
28.11.2024 (Thursday)	14:14 -15:14
09.11.2024 (Saturday)	16:00 -17:00
16.10.2024 (Wednesday)	14:10-15:10

4.2.3 Qualitative Interviews with residents

Short qualitative interviews with residents were conducted on 4 April 2025 using semi-structured interviews. For this purpose, all people who were present in public places in Stellwerk 60 between 16:55 and 18:17 were approached on site and served as a sample. All persons who voluntarily consented to the interview and the recording of the interview and who live in Stellwerk 60 were considered as interview partners. The declaration of consent used can be found in appendix 8. Due to the chosen approach, the interviews were mainly conducted in groups, as the people on site were predominantly gathered in groups during that time. To make the survey easily accessible and easy for everyone, the guidelines were based on just three questions, which were only expanded if necessary:

1. Are you satisfied with living at Stellwerk 60?
2. Why are you satisfied or what do you particularly like?
3. What do you find bad, challenging or what could be improved?

A semi-structured interview was chosen because on the one hand it allows comparability between the individual interviewees, but on the other hand it is also open to new, relevant aspects and can respond to unexpected or individually important questions (Adams, 2015).

A total of five group interviews (GI)[3] were conducted with residents. Table 3 provides a summarised overview of the groups with the respective numbers of participants and the length of the interviews. The respondent profile comprises five male and eight female participants. Eleven of them are residents of Stellwerk 60, while two participants live in the immediate surrounding area but, according to their own statements, visit the site on a weekly basis and are therefore also able to report on their experiences.

Table 3: respondent profile of the qualitative resident interviews

Group identification	Number of participating interviewees	Sex	Relation to Stellwerk 60	Duration of the interview
GI1	3	2 men, 1 woman	Residents	06:13 minutes
GI2	5	4 women, 1 man	Resident	10:28 minutes
GI3	2	2 men	Resident	9:32 minutes
GI4	1	1 woman	Resident	01:01 minutes
GI5	2	2 women	Visitors	01:10 minutes
Total	13	5 men, 8 woman		28:24 minutes

[3] In the further course, data from the group interviews are abbreviated as GI and a resident abbreviation R (GI-RX) is added in each case.

4.2.4 Qualitative Expert Interviews

In addition, expert interviews were conducted to provide a more in-depth, complementary structural-institutional perspective alongside the subjective resident perspective (Von Soest, 2023). The expert sample was selected based on professional involvement with the Stellwerk 60 project or substantial knowledge of the neighbourhood. Once the possible experts had been selected as described above, the selected experts were contacted by email and telephone in January and February 2025.

In total the sample included three experts: two employees from the City of Cologne (Department of Urban Planning and of Sustainable Mobility) and one member of the Stellwerk 60 residents' association. These experts were chosen due to their direct involvement in the planning and ongoing development of Stellwerk 60. The inclusion of the residents association was particularly relevant, as they played an active role in the planning process and remained closely connected to the residents. The member serves as a valuable link between the perspectives of professionals and those of the residents, offering both an insider's view and professional insights into the neighbourhood's development. All conducted interviews, including their field of expertise, the date and duration of the interview, are listed in Table 4.

All interviews were recorded with a written declaration of consent of the participants and later transcribed verbatim to ensure accurate data analysis. The informed declaration of consent form used can be found in appendix 8.

Table 4: Data on the expert interviews conducted

Interviewee	Professional Background of the Experts	Date of interview	Duration	Interview Mode
E1	A member of the Stellwerk 60 residents' association	12.02.2025	50 minutes	In person
E2	Department of Urban Planning	21.02.2025	33 minutes	In person
E3	Department of Sustainable Mobility	07.03.2025	Ca. 60 minutes	online

The interviews were conducted using a semi-structured approach. This method was chosen to allow for both targeted discussions on specific topics and open-ended exploration of expert perspectives (Adams, 2015). The interview guide was organised into four main thematic categories:

- Planning and implementation of car-free neighbourhoods
- The role of residential satisfaction in urban planning
- Evaluation processes
- Lessons learned, future perspectives, and potential challenges/ risks

Depending on the expertise and professional background of each interviewee, the specific questions within these categories were adapted to ensure a relevant and focused discussion. A selection of typical expert questions is provided in appendix 2.

4.3 Data analysis

This chapter describes the methods used to analyse the collected data. To this end, quantitative data analysis is described first (4.3.1), followed by qualitative data analysis (4.3.2) and finally the integration of the two methods (4.3.3) is presented.

4.3.1 Quantitative data analysis

The analysis of this data aimed to summarize the data, test the formulated hypotheses and identify significant patterns within the data set. These analyses were carried out using RStudio (2024.12.0), a software for statistical calculations and graphics.

Before conducting the statistical analysis, the data set was checked for missing values and, if necessary, some variables were reverse coded. There were no relevant missing variables but the answers not relevant (-1) were treated as missing values. Additionally, the item ‘feeling of restriction’ had to be reversed. This was the only item where 1 meant positive and 5 negative. For all other items, 1 was always negative and 5 was always positive.

In addition, before each statistical test was carried out, the preconditions were examined for each test, e.g. normal distribution, linearity, scale level and outlier values. As most questions are Likert scale questions, the scale level of almost all items is ordinal scaled. In addition, no normal distribution could be determined, which is why non-parametric methods were used in the analysis (Emons & Sijtsma, 2023). The used statistical tests, to investigate the relationships between perceived environmental quality, residential satisfaction and other relevant variables, are explained in more detail subsequently:

Descriptive statistics were used to provide an overview of the characteristics of the sample and key trends within the data. For categorical variables (e.g. household type, car ownership), frequency distributions and percentages were calculated to illustrate the composition of the

sample. For ordinal variables, which, since most questions are based on a Likert scale, affect almost all other items (e.g. age groups, length of residence, satisfaction ratings), measures of central tendency (mean) and dispersion (standard deviation) were calculated.

Correlation Analysis were conducted using Spearman's method to examine the linear relationships between the key variables, particularly between the various perceived environmental quality indicators and overall residential satisfaction, all of which are ordinal scaled. This approach enabled the identification of statistically significant correlations and the strength of these relationships. The correlations were interpreted on the basis of both size (effect size) and statistical significance (p-value).

Non-parametric analyses of variance using the Kruskal-Wallis (H-test) were carried out to investigate whether statistically significant differences exist between different independent resident groups (e.g. household type, age groups, length of residence, car ownership). This method was chosen due to the ordinal scale level of the dependent variables and the non-normal distribution of the data. Post-hoc tests (e.g. pairwise comparisons with Bonferroni correction) were used if significance was found in order to further investigate the group differences.

To ensure the internal consistency of the constructed indices for the perceived environmental qualities (e.g. mobility, spatial, social, functional and contextual dimensions), Cronbach's alpha was calculated for each index. According to literature, values above .70 are considered acceptable for research purposes and were interpreted accordingly (Cronbach, 1951).

4.3.2 Qualitative data analysis

For the qualitative analysis, Mayring's (2014) method of structuring content analysis was chosen, because this method allows a systematic, theory-driven analysis, offers a transparent and comprehensible procedure and provides clear guidelines for carrying out the analysis (Mayring, 2014). This method is particularly suitable for case studies due to its structured and systematic approach, which is nevertheless flexible in order to explore complex subjective experiences (Kohlbacher, 2006). Before analysis, the interview material was transcribed according to Dressing and Pehl (2018).

For the further analysis a combined deductive-inductive approach was chosen, to use the existing theory as well as to gain new insights from the material (Mayring, 2014). The complete coding guide, including definitions, anchor examples, and clear coding rules were

established for each category and can be seen in appendix 3 Table A. In addition, the final category system can be found in appendix 4.

The deductive component drew on the conceptual framework presented in Chapter 1.4, which utilises the Perceived Residential Environmental Quality Indicators (PREQI). This provided a thematic foundation structured around key dimensions: spatial, social, functional, contextual, and mobility-related qualities.

To complement the deductive framework, an inductive categorization was undertaken to capture recurring qualitative themes that were not considered in the theoretical model. Within Social Qualities, the subcategories ‘Neighbourhood Relations’, ‘Neighbourhood Events’, and ‘Community Organisations/Associations’ were created, prompted by the volume of statements in the top category (37 in total) and intended to improve thematic clarity. Similarly, ‘financial aspects’ were introduced as an inductive sub-category under ‘Additional influences’, as there were numerous references to financial issues that had not previously been recorded. The system was iteratively refined during the analysis, following Mayring's (2014, pp. 79-83) principle that new categories should only be introduced if the data could not be meaningfully subsumed under the existing categories. This approach ensured that the categories maintained a consistent level of abstraction and struck a balance between generalizability and specificity.

In accordance with the principles of qualitative content analysis, multiple coding was applied, to improve clarity and organization (Schreier, 2012). Each relevant interview segment was assigned both content-related codes and additional categories describing the type of experience or evaluation (e.g. positive, negative or ambivalent). These evaluations were guided by the formulation of the open-ended survey questions and interview prompts. This dual structure enabled a simplified analysis not only to recognize patterns in the themes but also regarding psychological perceptions, e.g. to directly identify how many positive experiences or criticisms there are overall. The categories of the evaluating functions are also included in the coding guide in appendix 4. To ensure a meaningful comparison, a common coding framework was developed and used for both the residents and the expert interviews.

Coding was performed using MAXQDA software (VERBI Software Consult Sozialforschung GmbH, 2024). After coding, thematic patterns and differences between the perspectives of residents and experts were analysed. The final coding structure serves as a basis for interpreting the results and provides a comprehensive understanding of the perceived

environmental quality and success factors for car-free living in the city. In line with recommendations for mixed methods research, qualitative data was descriptively quantified where appropriate (e.g., number of mentions) to illustrate relevance and support interpretative validity without implying statistical generalisation (Vogl, 2017; Kuckartz, 2018).

4.3.3 Integration of Quantitative and Qualitative Findings

As Bazeley (2024) emphasizes, integration is central to mixed methods research and crucial for generating added value beyond the insights provided by individual data strands. Given the wide range of possible integration strategies, this study employed the 'triangulation protocol' approach developed by O'Cathain et al. (2010), which is particularly suitable for convergent parallel designs. In this approach, both the quantitative and qualitative data sets were analysed independently. Integration occurred during the interpretation phase (see discussion), where findings are systematically compared, contrasted, and synthesized. Following Bazeley's (2017) framework, the process involves complementing and comparing findings, identifying patterns and contradictions, merging thematic results, and transforming diverse data into reasoned conclusions. The triangulation protocol, meaning the joint presentation of quantitative and qualitative data, can be found in appendix 5, table B. This table includes all quantitative and qualitative results compared.

4.4 Quality Criteria and ethical considerations

Ensuring the quality of scientific research is a key requirement for producing reliable and transparent findings. In a mixed-methods design that combines both quantitative and qualitative data, the reflection on and communication of quality criteria play an especially important role (Creswell & Clark, 2011).

Validity was primarily ensured by using the established PREQI framework (Bonaiuto et al., 2006; Fornara et al., 2010; Mao et al., 2015; Zhou et al., 2021) which helped to capture the relevant conceptual dimensions of residential satisfaction and environmental quality and thus strengthen construct validity. In addition, validity was supported by combining PREQI-based items with qualitative findings, enabling a broader perspective. This mixed-methods design allowed for methodological triangulation and cross-validation of the results (Kelle, 2014). Combining the perspectives of residents and experts also strengthened the validity of the qualitative results through perspective triangulation. Finally, a pretest and a feedback option within the online survey confirmed the clarity of survey items.

To ensure **reliability**, the quantitative data was collected using a standardized online questionnaire, which, as already mentioned, is based on the PREQI framework (Fornara et al., 2010) and ensures consistency between respondents. In addition, only fully completed data sets were taken into account in order to avoid distortions due to missing values. Internal consistency was also checked and ensured by measuring Cronbach's alpha. The data analysis was carried out using RStudio (2024.12.0) software, which enables transparent and reproducible analysis procedures (Field et al., 2014). Also for the qualitative part, a semi-structured interview guide was developed on the basis of the research questions, which was used uniformly for all interviews. The data was systematically analysed according to Mayring's content analysis, using clearly defined coding rules and a transparent category system to ensure consistent coding and analytical reproducibility (Mayring, 2014). In addition, the use of the MAXQDA software supported a structured and transparent coding process (Kuckartz & Rädiker, 2024).

Moreover, **ethical standards** were carefully considered throughout the research process, particularly in the qualitative parts involving personal data and participant interviews. To ensure compliance with the European Union's General Data Protection Regulation (GDPR), all interview participants received detailed information about the study and were asked to sign an informed consent of declaration form (see appendix 8). In addition, all data was anonymized. This approach allowed for analytical depth while at the same time preserving the identity of the participants both quantitative and qualitative. Participation was entirely voluntary, and participants were informed of their right to withdraw at any time without providing a reason. These steps ensure transparency, trust, and adherence to ethical research standards, particularly important in studies dealing with residential satisfaction and personal experiences in a neighbourhood context.

5 Results

This chapter presents the key findings of the study based on the analysis of both quantitative and qualitative data. The results are structured based on the three research questions. It begins by describing the descriptive statistics (5.1), which serves as the foundation for interpreting the subsequent analytical findings. Afterwards the impact of the environmental qualities on residential satisfaction and the perceptions of the car-free environment is examined (5.2), followed by additional influences such as socio demographics (5.3).

5.1 Descriptive statistics of the Quantitative Sample

The online survey was completed by 88 residents, all of whom reported living in Stellwerk 60. Respondents range in age from 12 to 79 years (M= 51, SD = 14). The average duration of residence is 7.7 years, with 61% (n = 54) having lived in the neighbourhood for over 10 years. Most households were families (60%), followed by couples (22%), single-person households (16%), and shared flats (2%). Table 5 provides a breakdown of sample characteristics by household type.

Table 5: Socio-demographic profile (by household type)

Household type	**Living alone**	**living as a couple**	**Family (adults with children)**	**shared flats**	**Total**
Number of households	14	19	53	2	88
Mean age	57	63	46	46	51
Mean level of income	3000 € -4000 €	3000 € - 4000 €	4000 € - 5000 €	>5000 €	3000 € -4000 €
Mean years of residence	7.8	8,7	8,3	9	7,7

Overall, education levels are high. Most residents (66%) have a university degree or A-levels (17%). Most participants have an income of more than 5000€ (25%) or in the range of 3,000–€4,000 (24%). Just five participants (6%) have an income of less than 2000€. The years of residence range between one and more than 10 years, with most people (n=54; 61%) living there more than 10 years.

The most frequently cited reasons for moving to Stellwerk 60 were the neighbourhood's location (59.1%), its car-free character (55.7%), and tranquillity (54.5%). Families particularly valued family-friendliness, quietness, and the absence of cars. Singles and couples similarly emphasised quietness, car-free living, and ecological values or public transport access. Less frequently mentioned were aspects such as design, sense of community, or price-performance ratio, indicating these were not primary motivators.

5.2 The influence of environmental qualities on residential Satisfaction in car free neighbourhoods

This chapter presents the empirical results to answer the first research question, which investigates which perceived qualities of the residential environment contribute to residential satisfaction or dissatisfaction in the car-free Stellwerk 60 neighbourhood. The presentation is

organised according to its thematic dimensions based on the PREQI model. For each dimension, the quantitative survey results are presented first, followed by the qualitative statements of the residents. The quantitative data in this chapter was primarily examined using correlation analysis.

5.2.1 Overall Residential Satisfaction and neighbourhood attachment in Stellwerk 60

General satisfaction and neighbourhood attachment were both quantitatively and qualitatively assessed. Both provide an overall assessment of the environment (Fornara et al. 2010).

Quantitative results

The resident survey reveals a high level of residential satisfaction¸ which is illustrated in figure 4. On a five-point Likert scale (1 = not at all satisfied, 5 = very satisfied), the average satisfaction score was M = 4.3 (SD = 0.90). General well-being in the residential environment was also evaluated positively (M = 4.2, SD = 0.96), as was quality of life (M = 4.01, SD = 0.99) and perceived quality of stay (M = 4.27, SD = 0.88). The question 'How does the fact that Stellwerk 60 is a car-free neighbourhood affect your personal well-being?' rated using a Likert scale, received the highest measured value of the items that measured general satisfaction. This was answered with a mean score of 4.77 (SD = 0.58), where 5 means very positive. Compared to their previous residence, respondents rated their current situation overall better (M = 4.01 (5 = Much better), SD = 0.99).

When asked which aspects contribute most to well-being ('*How satisfied are you with the following aspects of your living environment in Stellwerk 60?'*), respondents most frequently mentioned green spaces and tranquillity (each 51.1%), followed by bicycle-friendliness (38.6%), quality of stay (36.4%), public transport access and the neighbourhood kiosk (each 25%), and low pollution levels (23.9%) as illustrated in Figure 5. In contrast, one question asked about missing needs (*'In which areas are your needs and therefore your quality of life not*

sufficiently met? What do you think is not good?'). The selected elements with the number of mentions are shown in Figure 6.[4]

Figure 4: Perceived level of well-being, quality of life and residential satisfaction in Stellwerk 60

Neighbourhood attachment was measured with the item '*It would be very difficult for me to leave this neighbourhood'* and scored an average rating of 3.76 (SD = 1.30). It showed a significant correlation with overall satisfaction ($r = .42$, $p < .001$), suggesting that stronger emotional ties are associated with higher satisfaction.

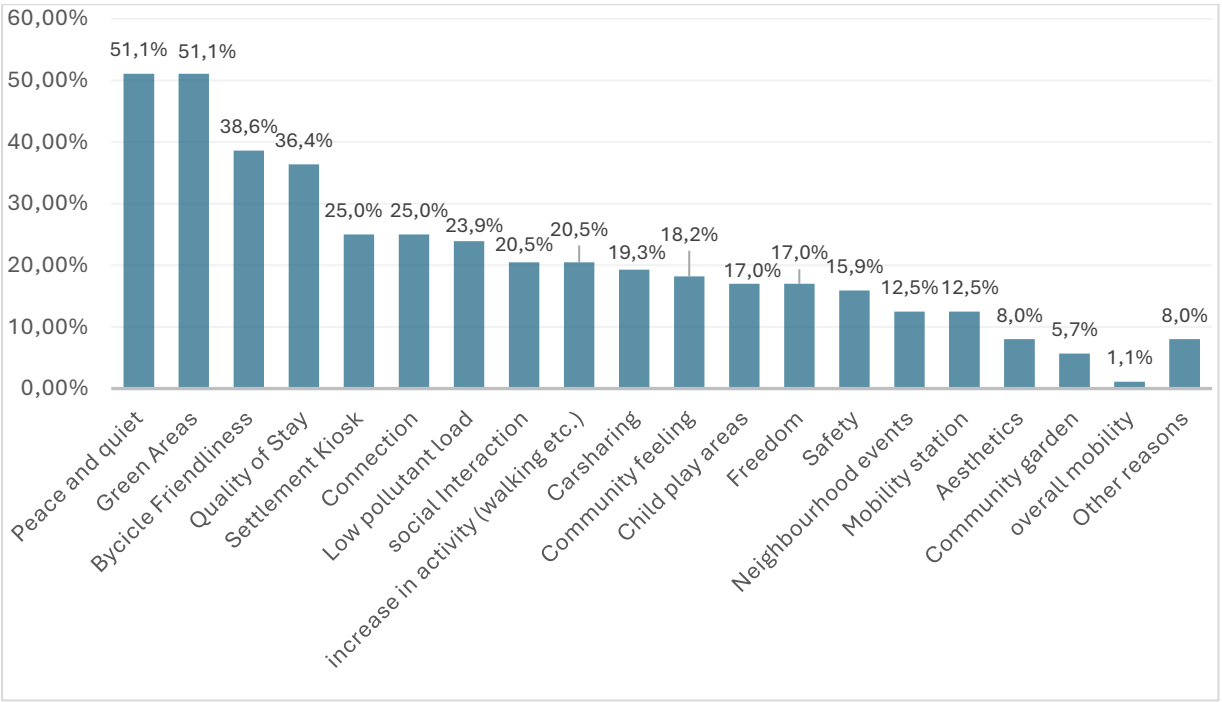

Figure 5: Nomination of various aspects that contribute to RS according to residents (in %) [5]

[4] *Notes: Variables had to be rated on a scale of 1-5 where 1 means a very low level and 5 means a very high level.*

[5] *Note: the question wording was 'Which aspects of the neighbourhood contribute most to your well-being?'. Up to 5 items could be selected.*

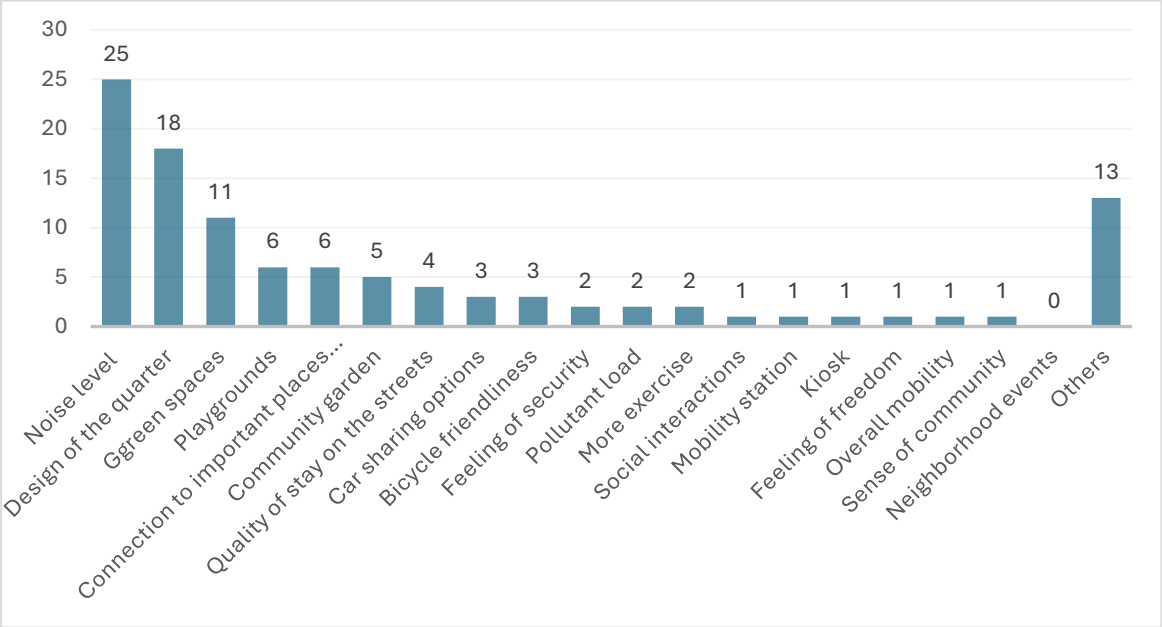

Figure 6: Nomination of various aspects and needs that are not satisfactory according to the residents [6]

Qualitative results

Overall satisfaction: The qualitative data indicate a generally positive overall residential satisfaction with the Stellwerk 60 development. All 11 residents interviewed responded affirmatively when asked whether they were satisfied living in Stellwerk 60. One expert also noted a perception of high quality of life within the neighbourhood, based on own observations (E3, line 659–660).

Residents described the settlement using expressions such as "green oasis in the middle of the city" (GI2-R3, line 8) and compared it to a vacation setting, which speaks for a positive rating:

> *"Ich finde immer, wenn ich nach der Arbeit mit dem Fahrrad von da reinfahre, ist das irgendwie so wie in so einem Urlaubsort." (GI2-R2, line 9-10).*

According to one expert, satisfaction can also be measured objectively, as the Stellwerk 60 is characterized by high demand for apartments, low fluctuation rates, and long waiting lists (E1, line 15–16). In addition, it has been described as a "flagship project" by one resident that demonstrates the practical feasibility of a car-free life and reflects a positive assessment:

[6] *Note: the question wording was 'In which areas are your needs and therefore your quality of life not sufficiently met? What do you think is not good? Up to 5 items could be selected.*

"Stellwerk 60 ist ein "Leuchtturmprojekt" aus meiner Sicht. Das zeigt, es geht. Sehr gut!" (OEQ-P28).

***Neighbourhood attachment**:* Some residents expressed that they are attached to the neighbourhood because they live there very happily overall: *„Das gefällt uns hier sehr gut. Wir wohnen hier schon seit 14 Jahren jetzt." (GI1-R1, line 10-11)*; *„Wir werden auch hier alt."* (GI2-R1, line 5).

However, it was also mentioned that a few residents experienced a weakening of neighbourhood ties and expressed a desire to move. The reasons given that have led to this dissatisfaction are e.g. noise pollution:

„für die Kinder und Jugendliche toll, aber für uns Anwohner sehr lärmintensiv. Das war neben dem Hauskauf ein wichtiger Grund für unseren Wegzug." (OEQ-P50, Pos. 15); *„Viele Nachbarn sind weggezogen, weil es ihnen hier zu laut ist." (OEQ-P43, Pos. 19)*

and unmet needs of particular groups: *„Ich gucke schon nach einer neuen Wohnung. Echt schade, dass das hier nur für Kinder und Familien ist." (OEQ-P47, Pos. 6)*

Additionally, the high cost of living makes it difficult for some residents to stay in the neighbourhood where they live:

" Reihenhaus geht hier gerade für 1 mio. verkauft. Können wir uns leider nicht leisten. Miete von 2000 Euro für 4 Zimmerwohnung auch nicht. Wir müssen als vierköpfige Familie bald wegziehen. Sehr schade, die Kinder haben es so toll hier" (OEQ_P8, Pos. 17)

5.2.2 Mobility

This chapter deals with the general mobility and transport situation in the car-free neighbourhood. First, the general car dependency in a car-free neighbourhood is presented, which deals with the need for a car and feeling of restriction. Second, the situation with the alternative mobility options is outlined.

5.2.2.1 Car dependency in a car-free neighbourhood and feeling of restriction

Quantitative Results

Among the residents in Stellwerk 60, 72.7% (n = 64) stated that they live without a car, resulting in 27.3% (n = 24) owning a private car (Figure 7).

When asked '*Do you feel restricted in your daily life by not having a car?*', measured on a five-point Likert scale (1 = not at all, 5 = very much), the average score was low with a mean

of 1.48 (SD = 0.83). No statistically significant correlation was found between perceived limitation and overall residential satisfaction (r = –0.09, p = 0.414). Similarly, there was no significant association between perceived limitation and general well-being (r = –0.02, p = 0.815).

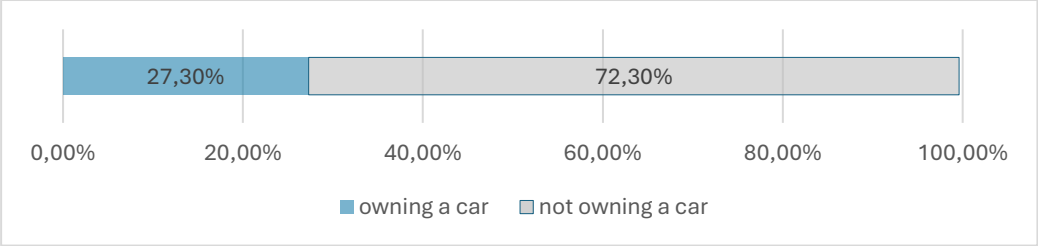

Figure 7: Proportion of Residents who own a car in Stellwerk 60

Qualitative Results

***Need for a car*:** The category captures residents' perceptions if they feel the need for a car or if they feel somehow restricted, which could affect satisfaction. The topic regarding the actual need for a car only came up in one group interview (G2). Thereby, one resident praised the advantageous location and the good cycling infrastructure, which enables her to cope with everyday life without a car. Other residents emphasised during that interview that access to a car for work purposes or activities outside the city was still important:

> *"Es kommt darauf an, wenn du dich auf die Stadt konzentrierst oder fokussierst, dann brauchst du nicht unbedingt ein Auto. Sobald du mal ein Wochenende oder auch Dinge außerhalb machen willst, bin ich an ein Auto angewiesen." (GI2-R4, line 72-75)*

From a planning perspective, experts acknowledge the need to balance car-free goals with the mobility requirements of all user groups, to ensure satisfaction:

> *"Auf der anderen Seite muss man natürlich auch immer transportieren, es gibt auch Menschen, die brauchen ihr Auto, aus beruflichen Gründen und sonst was. Und da muss man natürlich auch gucken, wie man mit dieser Nachfrage umgeht und das muss man irgendwie vereinen." (Expert 3, line 743-746)*

***Exception rules*:** This category emerged during the analysis, since it was a recurring aspect, which was expressed five times within the OEQ of the online survey and reflected the desire of some residents for improved exemption regulation and uncovers a current point of dissatisfaction (OEQ-P72, Pos. 17). One resident expressed the wish for a more flexible solution: *„Flexibles Konzept von Befahrbarkeit (in Notsituationen, die über den Krankenwagen hinausgehen)" (OEQ-P72, Pos. 17)*

In this context, the current taxi infrastructure is also criticized a few times because they are not allowed to transport residents to their homes even if they are ill, which, according to the respondents, leads to the exclusion and feeling of restriction of older, temporarily physically weak people (e.g. OEQ-P72, Pos. 4). One would also like to see more taxi ranks.

Further challenges which were mentioned include conflicts when residents falsely claim car-free status but still park nearby, causing frustration among neighbours (OEQ-P4). This issue is now managed by the city in partnership with the residents' association by restricting parking permits, as stated by Expert 1 and Expert 3.

5.2.2.2 Satisfaction with alternative mobility options

Quantitative Results

The results of the survey provide information on how well the car-free concept works in practice and to what extent alternative means of transport are perceived as accessible and sufficient. The generated mobility index showed an average rating of satisfaction with mobility of 4.45 (SD = 0.52) on a 5-point scale (5 = high satisfaction). No statistically significant correlation was found between the mobility index and overall residential satisfaction (p = 0.2) using Spearman's rank correlation.

Additionally, a more detailed analysis of the individual items was conducted, which revealed slight differences in satisfaction levels. The highest satisfaction was reported for the bicycle-friendliness of the neighbourhood (M = 4.80, SD = 0.51), followed by the mobility station (M = 4.55, SD = 0.77). The lowest mean score was observed for satisfaction with public transport (M = 4.05, SD = 0.99). The ranking of the mean values is illustrated in Figure 8.

Additionally, the correlation with residential satisfaction was also calculated for each individual variable, using Spearman's rank correlation. Significant positive correlations with general residential satisfaction were found for all individual mobility-related aspects, presented in table 6.

Another question was related to the use of alternative mobility options. Regarding the mobility station, most residents reported that they use it monthly (39.8 %, n = 13) or less than once a month (30.7 %, n = 13). 14.8% stated that they never use it (n = 27).

Car sharing services are used by 65.9% (n =58) of respondents. Of these, 9.1% (n = 8) also have their own car and 56.8% (n =50) stated that they only use car sharing services. The satisfaction with car sharing services was ranked as 4.14 on a 5-point Likert scale (SD = 0.8).

No significant correlation was found between satisfaction with car sharing and overall satisfaction (r = 0.15, p = 0.26).

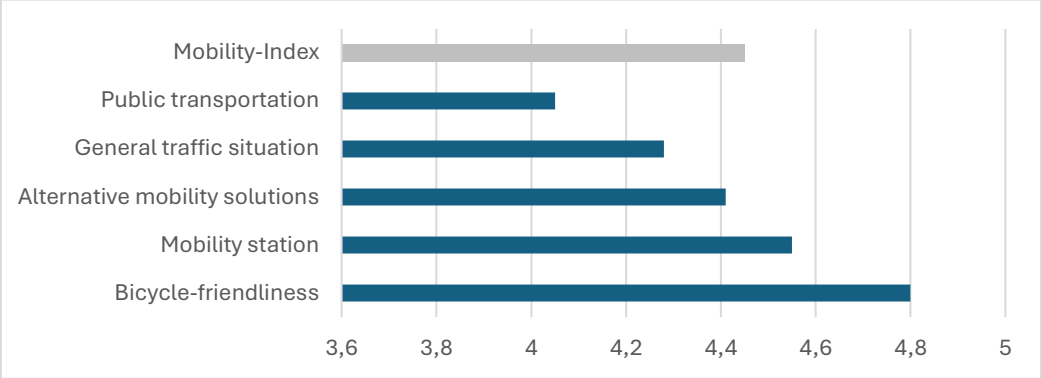

Figure 8: Mean satisfaction with transport and accessibility aspects [7]

Table 6: Correlation of Mobility aspects with residential satisfaction

Items	Spearman's rank correlation (r)	p- Value	Significance
Satisfaction with alternative mobility options (e.g., car sharing, cargo bikes)	0.29	0.006	Yes
Satisfaction with the general traffic situation	0.25	0.019	Yes
Satisfaction with bicycle-friendliness	0.23	0.030	Yes
Satisfaction with the mobility station	0.25	0.021	Yes
Satisfaction with public transport	–0.21	0.045	Yes (negative)

Qualitative Results

The mobility category was mentioned highly frequently by residents and experts (n = 40). As a result, further subcategories were formed inductively during the content analysis. The findings are presented below for each sub-chapter.

***Car Sharing offers*:** One resident evaluated Car sharing services as positively and considered it as cost-effective:

[7] *Note: satisfaction with various aspects of mobility was rated on a scale of 1-5, with 1 being very poor and 5 being very good.*

> *"Also ich, für meinen Teil, habe ja zwei Cambio Stationen zur Auswahl und für das, wofür ich ein Auto kaufe, lebe ich echt günstiger, als wenn ich eins hätte"(GI2-R2, line 59-61).*

Other resident expresses a desire for electric car sharing offers (OEQ-P5) or for general more car sharing offers (OEQ-P34), but without an evaluative assessment or conclusions on satisfaction.

During the observation times, car sharing cars were always available

Public transport: This mode of transport was criticised for not being a good alternative, since it takes up too much time compared to cars (GI2-R5) and as it is experienced as insufficient and unreliable:

> *„Solange der öffentliche Nah- und Fernverkehr so lückenhaft ist ist "autofrei" für viele keine Alternative!" (OEQ-P15, Pos. 15)*

These experiences were confirmed by the mobility expert, who emphasizes that currently there are some problems with the cologne transport company 'Kölner Verkehrs-Betriebe' (KVB), which according to him is a huge shortcoming ('*Riesenmanko'*) and that a good and reliable transport service, especially for car free living is important (E3, line 717).

Bicycle: One resident named the bicycle as the main means of transportation (G2-R2). In terms of bicycle friendliness, not many qualitative statements were made.

However, expert E2 recommended improving integration with the city-wide cycling network. The recommendation is to establish a continuous cycling route, possibly by converting connecting streets into a "*Cycling road* ". This would strengthen the bicycle infrastructure, which is vital for a car-free settlement, as expert E2 emphasises:

> *„Und was einfach sehr wichtig wäre, wäre nochmal diese Radwegeanbindung. Wenn man so eine autofreie Siedlung hat, die sind so aufs Rad angewiesen." (E2, line 687-689)*

During the observation, it was noted that a lot of people cycle through the estate and many bicycles are parked in the neighbourhood.

Internal practicability: This section mainly contains statements about safety when walking and cycling within the neighbourhood. A lot of criticism is voiced in this context, especially regarding the behaviour of cyclists and the lack of separation between pedestrian and cycling infrastructure. Residents express frustration with cyclists, including those on cargo bikes, who often ride too fast and fail to show consideration for pedestrians, especially children and elderly residents, leading to dissatisfaction:

"Wir sind über 70 und wären einige Male fast von Radfahrern oder solchen mit Lastenrädern umgefahren worden." (OEQ-P43, Pos. 4); "Radfahrer, besonders Lastenräder fahren zu schnell und rücksichtslos zu Fußgängern." (OEQ-P88, Pos. 17)

Accordingly, some pedestrians would like to see more safety and regulation of cycle traffic. To this end, it was suggested by participant OEQ-P24 that pedestrians and cyclists should be separated from each other, by OEQ-P26 that the long lanes that allow speeding should be interrupted, and by OEQ-P88 that pedestrian zones should be signposted with an obligation to cycle at a walking pace.

***Neighbourhood garage**:* Residents report mixed experiences, with the availability of the neighbourhood underground car park. On the one hand, it has been positively emphasised that they provide parking spaces for visitors and those who need a car, especially for work:

„Wenn du natürlich jetzt einen Job hast, wo du viel Auto fahren musst, kann ich das voll verstehen. Muss auch manchmal gegeben sein, dass man eine Garage hat." (G2-R2, line. 164-166)

Additionally, they are perceived as a good solution to solve various urban quality problems and to ensure a better quality of life:

"Quartiersgaragen/Parkhäuser lösen viele Probleme der mangelhaften Lebensqualität in Städten."(OEQ-P28, Pos. 19)

However, a lack of visitor parking spaces is perceived and criticised as a problem that leads to difficulties in accommodating guests (GI1-R1, line 23-26). Residents expressed a desire for larger or additional car parks nearby to accommodate visitors (e.g. OEQ-P15). Moreover, the location of the garage was also questioned, as cars are forced to drive through the surrounding residential core (OEQ-P8). Additional, negative assessments concerned the garage's design, with e.g. its exterior lights shining directly into apartments:

" Muss verkleidet werden, die Scheinwerfer leuchten ständig in die Wohnung, man erblindet fast in der Küche." (OEQ-P30, line 17)

One Export explained that additional space was left free for the neighbourhood garage so that more parking spaces could be built if it doesn't work out. This fallback level is viewed ambivalently by the experts: Expert E2 considers it useful (line 446), whereas expert E3 does not consider it necessary and complains more about the empty space it creates that cannot be used for better purposes (line 678-679).

As can be seen from the observations, this open space is currently being used by urban gardening groups for local community gardens, which received positive ratings in the OEQ of the survey.

Short-term parking: Some residents wish for the implementation of short-term parking spaces, especially for deliveries and care services, which are not provided:

> *„Es fehlt an kurzhalte Parkplätzen, alle Autos (Lieferdienste, kurz Besucher) stehen im Feuerwehr Wendekreis absolutem Halteverbot" (OEQ-P8, Pos. 15)*

This situation was also observed and confirmed several times during the observations. Additionally, one resident reported that Hermes occasionally drives onto the site without authorisation (OEQ-P82, line 17). To control access, the use of 'electronically controlled posts that not everyone can get in (OEQ-P82, line 17) is suggested.

Bicycle garage*:* Even though they were only mentioned twice, the bicycle garages received positive feedback. One of the residents praised their comfort and practicality:

> *„Sehr komfortable Fahrradtiefgarage! Um täglich radfahren zu können, ist es wichtig, dass man das Rad schnell draußen hat, es aber gleichzeitig sicher und trocken untergebracht werden kann." (EQG-P21, line 2)*

Expert E1 recommends implementing these garages in other normal residential buildings as well, as they have only had positive experiences with it in the neighbourhood. However, according to Expert E1, these could nowadays be designed even more efficiently with a second level system, so that even more bicycles can be accommodated (line 583-584).

***Mobility station*:** The mobility station (*'Mobilitätsstation'*) was not explicitly mentioned in the interviews but was mentioned in the online questionnaire by three residents as one place they like to use (e.g. OEQ-P23, pos.21). One expert describes the concept as the solution for the 'last mile' and positively assessed the additional shared use options by the station, such as beer benches and handcarts for events and activities:

> *„Und es kam dann der Sharing-Gedanke bei anderen Artikeln dazu. Wie z.B. die Biertisch-Garnitur. Das sind Sachen, die man nicht gerne zu Hause hat. Die Häuser oder die Wohnungen sind ja auch eher klein und teuer. Da hat man nicht gerne eine Biertisch-Garnitur drinstehen, die man dann vielleicht zweimal im Jahr benutzt. Da sind sehr viele Sachen für das Sharing, die man seltener braucht und ein bisschen klobiger sind oder unhandlich. Das ist eine gute Idee." (E1, line 106-111)*

Observations confirm that the station is used regularly. Especially on warm days, many children's toys such as Kettcars or outdoor tables and benches were borrowed. However, the size and implementation of the station were criticised by E1, since it is located in a former

living room and therefore does not offer much space. Expert E1 recommends that such mobility stations should be implemented in future, but that they should be larger (line 112-113).

Combined mobility offers: One important finding is the need to have various alternative mobility options and to be able to combine them with one another as expressed by the experts. This also includes the need for a mobility manager or mobility advisor to ensure that the alternative options are sustainable and well organised (E3, lines 512–514; 687–698; E2, line 529–539). Such a function would have to coordinate the services, maintain order, remove scrap bikes and advise newcomers on local transport options:

> *„Dass wir immer wieder jemanden haben müssen, also immer einen haben müssen, der immer wieder die Menschen animiert, auf ihre Fragestellung bezüglich des Mobilitätsverhaltens Nachzusteuern, weil man oft so sieht, dann werden da irgendwelche Lastenfahrräder gefördert, die sehen dann am Anfang noch sehr schön aus, dann werden die auch genutzt und irgendwann werden sie nicht mehr genutzt und stehen in der Ecke rum. Das hat ja bestimmte Gründe, warum das so ist. Und um solche Dinge dann zu ermitteln, ist so ein Mobilitätsmanager in so einem Quartier sehr wichtig, der dann auf die Leute auch eingeht, der sie vielleicht auch berät.“ (E3, line 506-514)*

5.2.3 Spatial and Design Aspects

This section provides an overview of how residents evaluate the physical and architectural features of Stellwerk 60, including green spaces, public space design, and the overall built environment. The results are presented in two sub-categories: Architectural and urban planning space and Greenspaces.

5.2.3.1 Architectural and urban planning space

Quantitative Results

The spatial index showed an average satisfaction of 3.83 (SD = 0.72) on a 5-point scale. The individual item ‘general design of the public space’ was rated with an average of 3.94 (SD = 0.90). Satisfaction with the ‘architecture and design of the buildings’ was slightly lower, averaging 3.43 (SD = 0.88). The analysis showed no statistically significant correlation between general satisfaction with the spatial environment and overall residential satisfaction, using Spearman's rank correlation ($r = -0.01$, $p = 0.9435$). Likewise, none of the specific spatial variables displayed significant correlations: green spaces ($r = 0.09$, $p = 0.4193$), the design of public spaces ($r = 0.01$, $p = 0.9758$), and the architecture and building design ($r = 0.14$, $p = 0.2331$).

Qualitative Results

The category architecture and urban planning space encompasses residents' evaluations of building aesthetics, density, volume and overall spatial planning. For clarity, it is divided into four inductively formed subcategories: general spatial planning, building density, architecture and design, and home design.

Overall spatial planning*:* Some residents reported negative experiences as they felt the neighbourhood was too small overall (GI3-R2 and GI3-R1) and one resident commented that the inclusion of private gardens was wasting a lot of common space (GI3-R2).

Expert E3 agreed and admitted that the district could and should be much bigger: "*man hätte eigentlich einen viel größeren Bereich nehmen können*" (E3, line 552-553). Expert E2 finds that the neighbourhood has in some parts a somewhat 'ghetto-like' feel in places, which, in his opinion, however, can generally be a problem with new housing estates.

Otherwise, the statements on the design relate only to the green areas, which are presented separately.

Building density: Five Participants of the online survey criticise the fact that the houses are too close together, which leads to dissatisfaction due to e.g. noise pollution and demand greater distances between the houses (e.g. OEQ-P68).

In contrast, one resident assessed the density as positive by praising the area's airiness:

> "*Also wir haben ja echt hier viel Luft."* (GI2-R2, line 53).

Architecture and design: One resident criticised the buildings as unattractive and monotonous, citing a lack of quality materials which leads to a poor assessment of the spatial quality:

> *„Es ist halt architektonisch hässlich, meines Erachtens, also einfach keine schöne Architektur, von den Materialien auch." (GI3-R2, line 66-67)*

As suggested by resident GI3-R2, more wood should be used, to improve the assessment of spatial quality. Other participants suggested making the houses more colourful (OEQ-P8, OEQ-P25) or planting flower meadows (OEQ-P25). One expert emphasizes that, from an urban planning perspective, the aim is to bring a certain quality to the buildings themselves, also with regard to resident satisfaction (E2, line 90-91).

Home design: Regarding the design of the houses, the size of the apartments was criticized as being too small and incorrectly designed, leading to a negative assessment of the spatial

quality. There is a desire by a few residents for more larger apartments, especially 4-5 room apartments:

> *"Bei uns sind das alles Dreizimmerwohnungen, da die Kinder, wenn die Kinder größer werden, ziehen die alle irgendwann aus, weil es einfach zu klein wird." (GI3-R1, line 77-79)*

Expert E1 confirms this criticism and sees the challenge for investors:

> *„Aber bei den Wohnungen, das ist nicht deren Klientel gewesen. Die haben irgendwie so eine Ein-, Zwei-Kind-Familie mit gutem Einkommen. Das ist so deren Klientel." (E1, line 342-343)*

On the other hand, the balconies and terraces of the apartments were praised and evaluated positive by those who have one and described them, for example, as *worth its weight in gold* ('*Goldwert*') (OEQ-P23, Pos. 21).

5.2.3.2 Green Spaces

Quantitative

Residents were asked to rate how frequently they use various places within the neighbourhood for spending time in Stellwerk 60. The most frequently used neighbourhood space are the green areas with a frequency of 12 residents reporting using them every day. Table 7 shows all the frequencies of use of some places in the neighbourhood green areas indicated by the residents.

Table 7: Frequencies of use for selected neighbourhood places as reported by residents.

	Daily	Several times a week	Once a Week	Less often	Never	total
Child play areas	2	13	10	31	32	88
Courtyards	4	9	11	44	20	88
Benches	4	5	23	41	15	88
Green Areas	12	19	21	31	5	88

Note: The wording of the question was 'How often do you use the following places and facilities in Stellwerk 60 as a place to stay?'

Additionally, when asked which aspects contribute most to their well-being, 51.1% of respondents cited green spaces, making them one of the two most frequently mentioned factors alongside tranquillity.

Green spaces also received the highest overall rating of all spatial environmental quality features assessed, with an average score of 4.11 (SD = 0.84). However, no statistically significant correlation was found between the perceived quality of green spaces and overall residential satisfaction (r = .08, p = 0.4).

Qualitative

***Neighbourhood Green**:* Residents have had different experiences regarding green areas. A few appreciate the greenery, but without conclusions on satisfaction: *"Es ist grün, das ist schön." (Group 3, Pos. 15).* Additionally, there is also one resident who rates the community garden as very positive: *„Gartenprojekt neben Parkpalette. Lieblingsplatz!!!!" (OEQ-P??, Pos.23).*

Most others see challenges and opportunities for improvement. For example, residents wish for more facade greening (e.g.OEQ-P3) and additional trees and shrubs (e.g.OEQ-P10). The reason given was to improve the microclimate, which is experienced as too hot in summer:

> *„Man merkt im Sommer, dass die Begrünung noch nicht ausreicht, die Hitze staut sich auch in unserer Siedlung." (OEQ-P36, Pos.17)*

Residents have taken matters into their own hands, creating community gardening projects and rewilding areas, but as one resident reports, there are difficulties in getting approval for such initiatives (GI3, line 117-121).

***Usability for relaxing and social meetings**:* Residents have had mixed experiences with the green areas and common spaces in the neighbourhood. Six residents criticize within the online survey the lack of tranquillity in the existing green areas, which are perceived as too noisy, especially in the afternoons and on weekends (e.g. OEQ-P88, Pos. 6).

In contrast, other residents expressed positive experiences, stating that the green spaces gave them the opportunity to relax (GI2), walking the dog (OEQ-88; observation), socialise (GI2; observation), engage in activities such as playing football (OEQ-P50; observation) and extending the living space, which all improves their residential satisfaction:

> *„Und obwohl wir hier in diesen Mietwohnungen mit teils begrenztem Wohnraum leben, kann man die Fläche, auf der man sich so bewegt, hier so toll erweitern (guckt sich in der Grünfläche um). Das gefällt uns hier sehr gut. Wir wohnen hier schon seit 14 Jahren jetzt." (GI1-R1, Pos. 8-11)*

During the COVID-19 pandemic, the outdoor areas were particularly appreciated as they enabled residents to maintain social contact while adhering to distancing rules, as stated in GI3. However, the residents also identified some challenges, such as a lack of benches and

seating areas, especially under trees and near to the settlement kiosk (e.g. OEQ-P72, OEQ-P27).

Additionally, a few residents would like to see more inviting community spaces, like a designated "village square", whereby, however, the current situation was not really criticized:

> *„Es sollte auch einen Siedlungsmittelpunkt geben, wie z.B. einen ausgewiesenen "Dorfplatz" mit einem Gemeinschaftsraum“ (OEQ-P2, Pos.17)*

***Child play areas and child friendly space design**:* This sub-category covers the perception and evaluation of play areas and the overall child-friendly design of the residential environment, including aspects such as safety, accessibility and the play value of outdoor spaces. Through the observations it could be identified that there is a wide range of facilities for families and children in the neighbourhood, such as various playgrounds, sports fields, soccer fields and go-karts for common use.

A large number of residents report positive experiences and praise the safety and freedom of children to play and move freely in the streets and squares without fear of traffic. This is described by one resident as a unique and valuable aspect, especially in a large city like Cologne:

> *“Der Aspekt, dass sich Kinder, auch kleinere, frei und ohne Angst vor Verkehr auf der Straße bewegen können, ist in einer Großstadt wie Köln einmalig und sehr wertvoll.“ (OEQ-P26, Pos.6)*

According to one expert, the entire neighbourhood can be used as a play area due to the lack of cars: *„Hier ist einfach der Außenbereich der Spielplatz.” (E1, Pos. 314).*

However, they also expressed some criticisms and challenges, such as the small size and lack of shading on the playgrounds, as well as the uneven distribution of play areas throughout the settlement, which rather expresses dissatisfaction:

> *„Also man hat einfach immer nur so punktuell eine Sache, und dann so 50 Meter weiter ist wieder eine Sache, anstatt irgendwie mal zwei große zu machen. Und das finde ich echt mist.“ (GI3-R1, Pos. 31-32)*

Residents would like to see larger, better-designed playgrounds (e.g.OEQ-P70) and more play areas for older children (e.g.OEQ-P25), as well as wishing for some water playgrounds (e.g.OEQ-P8). However, these wishes were expressed without criticizing the current situation.

***Use of neighbourhood places and green spaces**:* During the interviews, there were a lot of people on the green space and using it. The third group (GI3) used a playground with their

children, for example, while the second group (GI2) sat in the green area with beer benches from the mobile station and a cold drink from the settlement kiosk, enjoying the nice weather.

In addition, the following locations were selected in the online survey as places residents like to stay or use: Urban Gardening (OEQ-P3), Playgrounds (OEQ-P27), the 'Lummerland' Sports hall (OEQ-P37), and their own gardens (OEQ-P51). Only the usage was mentioned here, but no rating that could give any indication of satisfaction.

Further qualitative observations show that most of the residents' activities are centred on the main green space and the playground. The large communal meadow seems to be the centre, while smaller play areas and inner courtyards remain largely unused. Although the side streets are frequented by cyclists, they do not invite residents to linger, as determined during the observations. The benches were always well used, but again only in the main green area. A low stone wall near the kiosk also seems to serve as an informal meeting place.

5.2.3.3 Accessibility and Location

Quantitative Results

The average satisfaction with accessibility was rated positive with an average score of 4.51, where 5 means very high satisfaction (SD = 0.74). Satisfaction with the connection to the city centre is rated similar (M = 4.52, SD = 0.80), while the connection to key places is perceived to be slightly worse (M = 4.43, SD = 0.78). The ranking of the mean values for satisfaction with the connection of the neighbourhood is illustrated in figure 10.

Despite the high level of satisfaction with the connection, no significant correlations between the connections and the perceived satisfaction could be determined: general accessibility (r = -0.01, p = 0.9) and accessibility with city centre (r = 0.05, p = 0.6).

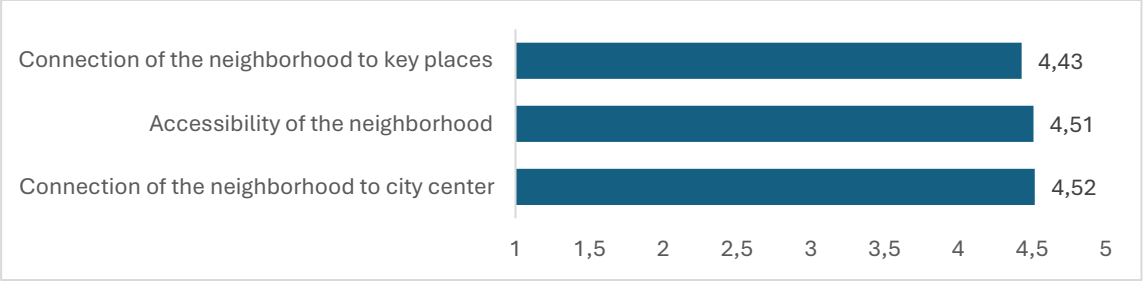

Figure 10: mean satisfaction with the connection of the neighbourhood [8]

[8] *Note: The questions were about how satisfied the respondents were with certain level of connection. A score of 1 means not satisfied at all and 5 means very satisfied*

Qualitative Results

In general, residents made few statements about the location and connection. One resident complained that due to the location it takes longer to walk to the metro (GI2, line 48-51) and group 2 discussed their distances to important places like jobs and doctors, which were different for everyone in that group.

However, expert E3 praised the 'attractive' location and centrality of the neighbourhood, which is needed to reach satisfaction:

> *„Und da war wie gesagt, Nippes deswegen so attraktiv für dieses Stellwerk 60, weil es so zentrumsnah ist, weil ich direkt die s bahn da und da hab, die ich fußläufig erreichen kann." (E3, Pos. 746-748); „Deswegen war es von vornherein schon attraktiv, aber er hat eine gewisse Qualität mitgebracht, und die muss man natürlich haben und wenn man sie nicht hat, muss man sie erzeugen" (E3, Pos. 758-760)*

Also, expert E2 emphasised that this centrality is important for a car-free district:

> *„Aber es sollte halt irgendwo, wenn man so eine Siedlung plant, vielleicht wirklich so sein, dass es so zentral ist, dass man auch relativ schnell einkaufen gehen kann und solche Sachen. Das haben wir halt hier gehabt." (E2, Pos. 431-433)*

5.2.4 Social and Community Factors

Quantitative results

The social index, reflecting overall satisfaction with social aspects, yielded a mean score of 3.87 (SD = 0.73). A significant positive correlation was found between the social index and overall residential satisfaction ($r = 0.45$, $p < 0.001$). The individual item, measuring social satisfaction, yielded a similar mean of 3.88 (SD = 0.91) and revealed a particularly strong positive correlation with overall residential satisfaction ($r = 0.60$, $p < 0.001$). The average rating of the *sense of community* was 3.3 (SD = 1.2), which indicates a moderate level of perceived integration into the local community. The correlation between sense of community and satisfaction was significant ($r = 0.34$, $p = 0.0014$). Table 8 provides an overview of the social dimension statistics.

Participation in *neighbourhood activities* occurred primarily monthly (n = 30) or less frequently (n = 40), with only 4 participants engaging weekly and 14 stating they never participated. Overall, 81% of respondents (n = 64/79) perceived the number of neighbourhood activities as sufficient. In contrast, 6% (n = 5) expressed a desire for more offerings, another 6% (n = 5) stated they had no opinion, and a further 6% (n = 5) indicated that neighbourhood

activities were not necessary for them in principle. Notably, no one considered the number of activities to be excessive.

In terms of *social contact opportunities*, the item "*How easy is it to get to know people in Stellwerk 60?"* had a mean of 3.65 (SD = 0.92). A significant positive correlation with overall satisfaction was found (r = 0.40, $p < 0.001$). When asked 'whether it is easier to form social contacts' in Stellwerk 60 compared to other neighbourhoods, 51 respondents answered "yes," 30 perceived no difference, five had no comparison, and none rated it as more difficult.

Regarding places where encounters take place, the most frequently mentioned location was the street (32.3 %, n = 21), followed by neighbourhood events such as summer festivals and flea markets (24.6 %, n = 16), and participation in the residents' association and working groups (26.2 %, n = 17). Playgrounds also served as important meeting points (15.4 %, n = 10), while the settlement kiosk was mentioned only once (1.5 %).

Additionally, the frequency of use of the common room "Kaffe Kessel" was assessed, revealing that it is rarely utilized by residents; 50 participants reported never using it, 33 indicated usage less than once per week, four used it about once a week, one used it more than once a week, and none reported daily use.

Lastly, perceived *safety* was also assessed and rated highly with a mean value of 4.69 (SD = 0.57). This item also correlated significantly and positively with residential satisfaction (r = 0.39, $p < 0.001$).

Table 8: Overview of the social dimension statistics

Social-Items	Mean	Correlation	Significance
Index	3,87	r = 0.45	$p < 0.001$
Safety	4,69	r = 0.39	$p < 0.001$
Overall social satisfaction	3,88	r= 0.60,	$p < 0.001$
Social contact opportunities	3,65	r = 0.40,	$p < 0.001$
Sense of community	3,3	r = 0.34	$p = 0.0014$

Qualitative results

This category includes all aspects related to social interactions, mutual support, and the sense of community in the car-free neighbourhood. The subcategories include *neighbourhood relations*, *neighbourhood events*, and the role of *community associations*.

***Neighbourhood relations*:** Some residents report positive experiences in establishing social connections within the neighbourhood. Several residents state that they have formed friendships with neighbours, partly due to the spatial structure that facilitates spontaneous encounters and interactions in the shared outdoor areas.

The design of the public spaces, which encourages social contact, is described as a major enabler of regular informal meetups among neighbours by one group (GI3). Some interviewees even highlight that they live close to long-standing friends, which strengthens their sense of belonging and improves satisfaction.

***Neighbourhood events*:** According to expert E1 there is a generally high level of civic engagement. He emphasizes the exceptional density and activity of resident-led working groups, describing them as a central element of the neighbourhood's identity:

> *"Auch diese Arbeitsgruppen, die wir haben. In dieser Ballung auch. Das ist schon außergewöhnlich" (E1, line 315–316)*

He also stated that the working groups are diverse and address various topics such as mobility, climate, energy supply, and urban gardening. Notably, some of them have existed for several years and require ongoing commitment from participants, as in the case of the mobility stations and the energy self-sufficiency project (E1). To facilitate social meetings, the spatial design also includes a common room and a communal kitchen.

> *„Oder hier Kochkessel. Das ist unten rechts. Wir haben hier eine komplett eingerichtete Küche. Die kochen einmal im Monat oder zweimal im Monat." (E1, Pos. 289-290)*

However, some respondents point out that these activities are not inclusive of all demographic groups and favour families, children and the elderly, reducing their satisfaction (e.g. OEQ-P68). For example, one resident criticises that in his perspective many events are tailored primarily to families, leaving childless adults feeling excluded:

> *"Prinzipiell gibt es sehr viele schöne Angebote, die sich aber sehr an Familien mit Kindern richten. Als Kinderlose fühlt man sich oft nicht angesprochen" (OEQ-P36, Pos. 8)*

Other residents share the wish for more events aimed at teenagers (OEQ-P68) and childless adults (OEQ-P54).

One resident also expressed dissatisfaction with how such events are communicated:

> *"Die Kommunikation der Events ist nicht optimal. Man muss selbst hinterher sein, dass man alles mitbekommt." (OEQ-P25, Pos. 8)*

Expert E1 mentioned the lack of a sufficiently large community space, which he sees as an obstacle to strengthening community cohesion. In his opinion, the existing space is too small.

Some critical voices highlight social tensions arising from the dense urban form and the close proximity of dwellings (e.g. OEQ-P 48). Residents report negative experiences that consideration and respect for others are not always practiced, especially with regard to noise and disturbances. One resident links this issue directly to the dense urban design:

> *"Dadurch wohnt man viel enger zusammen. Deswegen müsste mehr Rücksicht genommen werden. Leider ist das Gegenteil der Fall." (OEQ-P33, line 19)*

As part of the observations carried out, the extent to which contacts take place between residents in the neighbourhood was examined. Numerous encounters between people were observed, particularly in the park of the large green area and their playgrounds. Most of the social interactions were observed among children. The community room "Kaffe-Kessel" was also examined more closely as a meeting place. During the observation period, it was only once used by a group.

***Neighbourhood association**:* The involvement of a residents' association was mentioned positively. One expert described the initiative as being both community-driven and supported by the administration, which fills the settlement with life and helps to increase satisfaction:

> *„Aber allein, dass man das durch einen Verein initiiert worden ist und nach vorne getragen worden ist, von der Verwaltung aber auch stark unterstützt worden ist, hat das Ding auch irgendwie Leben." (E2, line 570-572)*

The expert also identified this kind of bottom-up initiatives as a valuable element of successful project development. According to him, resident-led engagement, as is the case in Stellwerk 60, can lead to more dynamic and lively results than pure top-down planning:

> *„Und das sind immer die Sachen, die eigentlich am spannendsten werden, die so ein bisschen graswurzelmäßig von unten kommen und nicht von oben geplant werden. Und das ist zum Beispiel wirklich was, was man hier daraus lernen kann, dass man viel mehr eigenverantwortlich auch die Leute da mal machen lässt und guckt, wie man da hinkommt." (E2, line 579-583)*

5.2.5 Functional Aspects: recreational, commercial and welfare services

Quantitative results

The mean value of the calculated functional index scored a mean value of 3.29 (SD = 1.08). A small but significant correlation with overall satisfaction (r = 0.21, p = 0.048) was found. When analysing the individual items, supermarkets (M = 4.52, SD = 0.66) and shops for daily needs (M = 4.24, SD = 1.34) were rated most positively. In contrast, religious services (M =

0.78, SD = 2.54) and sports activities (M = 2.88, SD = 2.33) were rated lowest. All mean satisfaction values of the functional facilities are shown in Table 9. A significant correlation with satisfaction (r = 0.22, $p < .05$) was only found for the provision of entertainment services.

Table 9: mean and SD from residential satisfaction with functional aspects

Items	Mean	SD	Significance
Supermarkets	4.52	0.66	no
Shops for daily needs	4.24	1.34	no
Medical care	3.88	1.95	no
Sports activities	2.88	2.33	no
Entertainment offer	3.49	1.92	$p < .05$
Cultural offer	3.23	2.00	no
Religious services	0.78	2.54	no

Note: A score of 1 means not satisfied at all and 5 means very satisfied

The use of the settlement kiosk was also recorded as part of the functional dimension. The use of the settlement kiosk varied greatly among the respondents. Most stated that they visit the kiosk several times a week (34.1 %, n = 30) or once a week (31.8 %, n = 28). Only a few people use the kiosk every day (3.4 %, n = 3). 27.3 % (n = 24) visit the kiosk less than once a week, and only 3.4 % (n = 3) stated that they never use it.

Qualitative results

According to Fornara et al. (2010), this dimension was divided into further subcategories: commerce, leisure and social. Commerce includes everything that has to do with shops for daily needs, while leisure includes all elements in the neighbourhood that have a leisure function, such as sports facilities and socio-cultural activities. The welfare category includes the functions of school or social services.

Commercial*:* Two residents feel that a packing station (OEQ-P5, OEQ-P79) and one resident that a supermarket is missing and would be a valuable addition (GI3-R1), but without criticizing the current situation or drawing conclusions about satisfaction. The presence of the small kiosk on the estate is seen by some residents as a good compromise, as it offers a range of basic products, thus fulfilling their needs:

"Das ist ja wie so ein Tante-Emma-Laden. Da gibt es ja eigentlich alles." (GI2-R2, line 23-24)

Expert E2 emphasised that they have adopted the establishment of a community-oriented kiosk in other new housing estates, as they consider it within urban planning to be a good idea.

Recreational: Many residents express a desire for more adult-oriented amenities and feel that their needs are currently not sufficiently met. Thus, residents wished for implementing a bar (e.g. GI2, OEQ-P55), a biergarten (OEQ-P74), cafes (e.g. OEQ-P37), and more diverse leisure options (e.g. OEQ-P8). Here, the most popular wish was for more sports facilities beyond just those for children, such as basketball courts, volleyball nets, and table tennis:

"Es könnte mehr Sportmöglichkeiten gebrauchen (mehr Tischtennisplatten, Basketball, Beachvolleyball...)" (OEQ-P3, Pos. 15); „Gelegenheiten für "Urban Sport" wären toll (Skaten, City Roller, Bikes)." (OEQ, Pos. 15)

There is the impression that the current offer is primarily focussed on families with small children and that singles, childless adults and young people remain underserved, which can lead to dissatisfaction (e.g. OEQ-P47): "*Als Erwachsene (mit erwachsenen Kindern) werden unsere Bedürfnisse nicht wahrgenomme."(OEQ-P54, Pos.19).*

Welfare Service: As two residents stated there is a need for a care support centre for older and disabled residents, as well as a lack of cleaning staff to assist elderly residents*: „Es sollte einen Pflegestützpunkt für ältere und eingeschränkte Menschen vor Ort geben"* (OEQ-P62, Pos. 17). This statement again contained no criticism of the current situation or any kind of evaluation.

The expert E2 mentioned conflicts and difficulties they had during planning for new schools, due to higher demand as expected:

„Und wir hatten riesige Probleme, die ganzen Kinder unterzukriegen in den Grundschulen, die sonst noch hier drumherum waren." (E2, line 348-349)

5.2.6 Contextual Aspects: Environmental health, upkeep and care, and pace of live

Quantitative results

The created context index yielded a mean score of M = 3.52 (SD = 1.02). A statistically significant positive correlation was found between the contextual index and overall residential satisfaction (r = 0.578, $p < 0.001$). Table 10 shows the individual items of the contextual dimension in descending order of their mean values and provides an overview of how the individual aspects were assessed and how strongly they correlate with general residential

satisfaction. The highest satisfaction was reported for cleanliness (M = 3.74, SD = 0.94), closely followed by a calm atmosphere (M = 3.69, SD = 1.61) and peace and quiet (M = 3.68, SD = 1.59), as well as residents' care for the neighbourhood (M = 3.68, SD = 1.01).

Table 10: Mean scores, standard deviations, and correlations with overall residential satisfaction for contextual dimension items (sorted by mean).

Variable (Item)	Mean	SD	Correlation with RS (r)	Significance (p)
Cleanliness	3.74	0.94	0.60	p < .001
Calm atmosphere	3.69	1.61	0.57	p < .001
Residents take care of the neighbourhood	3.68	1.01	0.41	p < .001
Peace and quiet	3.68	1.59	0.60	p < .001
Something interesting happens every day	2.84	0.97	0.36	p < .001

All items showed significant positive correlations with overall residential satisfaction, with coefficients ranging from r = 0.36 to r = 0.60 (all p < .001). The strongest association was found for "cleanliness" (r = 0.6, $p < .001$), and "peace and quiet" (r = 0.6, $p < .001$).

Qualitative results

Pace of life: This category deals with impressions of how relaxing or stimulating the neighbourhood is perceived to be. Residents reported a mix of positive and negative aspects. On the positive side, the area has a village-like character as one resident stated, which in the context of the conversation was to be seen as a positive assessment:

> *„Man hat nicht das Gefühl, in einer Großstadt wie Köln zu leben. Es ist ein ländliches Gefühl hier."(GI1-R1, Pos. 6-7)*

Additionally, one expert (E1) reported that the neighbourhood is relatively stimulating and that there is always something going on, which could also be observed:

> *„Wenn man hier samstags bei schönem Wetter zumindest oder sonntags hier durchgeht, dann ist schon richtig was los. Das sieht man schon. Das hat man woanders nicht."(E1, line 311-312)*

However, many residents experience this stimulation as a kind of stress, as it becomes very loud, which is reported separately in the next category.

***Environmental health**:* This category includes statements about the presence of air and noise pollution, as well as sustainability aspects. Noise pollution was by far the most frequently addressed (n=53) and criticised (n=45) topic. The criticism is made about the significant noise issues that negatively impact the satisfaction of many residents as they reported:

> *„Der ewige Lärm (Kinder, Jugendliche, Erwachsene) ist wirklich unnötig!" (OEQ-P20, Pos. 6); „Die Lautstärke ist ein echtes Problem." (OEQ-P50, Pos. 19)*

One resident says that he finds it louder in the car-free area than on busy roads:

> *„Autofrei ist nicht ruhig. Wir wohnen hier viel lauter als früher auf der Luxemburgerstraße." (OEQ-P56, Pos. 19)*

The main problems mentioned are excessive noise from children, youth, and adults using the green spaces (OEQ-P20), playgrounds (OEQ-P42), football training (OEQ-P57) and sports facilities (OEQ-P14), as well as noise from the nearby kindergarten playgrounds (OEQ-P48), the kiosk (OEQ-P49), and deliveries for the kiosk (OEQ-P49).

The noise seems to be particularly problematic for residents living in the apartment buildings surrounding the green areas, who often cannot use their balconies or open their windows due to the disturbance:

> *„Dann ist es so laut, dass wir nicht auf dem Balkon sitzen können. Wir müssen dann auch die Fenster schließen. Das ist besonders schlimm, weil wir eine Zwei-Zimmer-Wohnung haben, deren Fenster nur nach Westen zu den Grünflächen beim Kindergarten gerichtet sind." (OEQ-P43, Pos. 15);„Die sehr viel genutzten Tischtennis-Platten stehen so nah an den Wohngebäuden, dass es für die dortigen Mieter sehr laut ist." (OEQ-P14, Pos. 15)*

Among other things, the construction method is criticised for the noise, because it makes a lot of noise and everything is too close together (OEQ-P80). Some residents also mention concrete solutions and suggestions for improvement. Resident OEQ-P49 suggested that playgrounds and table tennis tables should be a little further away from the houses and resident OEQ-P43 mentioned that quiet times should be signposted and adhered to. Another resident said that the flats on the green areas should also have windows on the other side:

> *„Um Grünflächen herum sollten nur Wohnungen sein, die auch Fenster in andere Richtungen haben. Sonst hat man gar keine Möglichkeit, dem Lärm auf den Grünflächen auszuweichen." (OEQ-P87, Pos. 19)*

One expert explains the perception of noise by explaining that loudness is a relative perception and due to the in his opinion actually very quiet area, every noise source is perceived as much louder than the same source elsewhere (E1, line 197-200). In addition,

Expert E1 said that the noise emissions in the neighbourhood according to him are much lower than elsewhere.

In contrast, there are two residents who find the area very quiet and report as positive experiences: *"Ruhig. Vogelgezwitscher."* (GI3-R2, line 15). However, expert 2 reports that he himself perceives the neighbourhood as very loud.

No statements were made on air pollution, but expert E1 residents stated that there are already some efforts to improve climate resilience, including through the working groups, but that more is still being done, and that more solar panels are particularly desired in this context (r.g. OEQ-P42).

Upkeep and care: Regarding the environmental condition, there are some concerns about insufficient lighting in some areas (e.g. OEQ-P2), issues with littering (OEQ-P63), dog waste (OEQ-P15), and a desire for better maintenance of green spaces:

> *„Ich wünsche mir ein gepflegtes Umfeld (saubere Straßen und Wege) und gepflegte Grünanlagen." (OEQ-P46, Pos. 6)*

However, during the observations, the neighbourhood always appeared clean and tidy.

5.3 Additional Influences on Residential Satisfaction

This chapter examines factors that influence residential satisfaction in order to answer research question 2 about differences in the perception of environmental quality and satisfaction between the resident groups in Stellwerk 60. To this end, demographic influences such as household type (5.3.1), age (5.3.2), income (5.3.3), length of residence and car ownership (5.3.5) are examined, primarily through statistical group comparisons.

5.3.1 The impact of Household Types

Quantitative Results

To investigate these relationships, a series of Kruskal–Wallis tests were conducted given the non-normal distribution of many variables. Furthermore, Dunn post-hoc tests were applied where appropriate. The household type was categorised into singles, couples without children, and families with children. There were several statistically significant group differences between the household types, all of which are shown in table 11.

Table 11: Significant impacts of household types on dependent variables

Variable	χ^2	p-Wert	Signifikanz	POST HOC
Overall Residential satisfaction	11.845	.003	**	Differences between Families (M=4.6) and singles (3.7) (p = 0.004)
Sports activities	6.938	0.031	*	Differences between Families (M=3.4) and singles (M=1.2) (p = 0.026)
Cycling friendliness	6.393	0.04		Post-hoc adjusted p-values indicate no significant pairwise differences Singles (M=4.6), Couples (M=4.6), Families (M=4.9)
Mobility station	10.012	0.007	**	Difference between families (M=4.8) and couples (M=4.2) (p = 0.08).
Residents take care of the neighbourhood	6.018	0.049	*	Post-hoc adjusted p-values indicate no significant pairwise differences Singles (M=3.1), Couples (M=3.4), Families (M=3.9)
Influence of car-free living on well-being	9.886	0.007	**	Differences between Families (M=4.9) and singles (M=4.4) (p = .03)
Quality of stay	7.801	0.02	*	Post-hoc adjusted p-values indicate no significant pairwise differences Singles (M=3.9), Couples (M=3.9), Families (M=4.5)
Neighbourhood attachment	6.151	0.046	*	Between Families (M=3.9) und Couples (M=3.2) (p =0.07)
Satisfaction car sharing	9.886	0.007	**	Differences between Families (M=4.1) and singles (M=4) (p = 0.026)
Green areas	8.544	0.01	*	Differences between Families (M=4.1) and singles (M=4) (p = 0.03)
Playgrounds and leisure areas	21.617	<0.001	**	Differences between families (M=4)-singles (M=3.9) (<0.001) and families-couples (M=4.2) (<0.01)
Settlement kiosk	6.867	0.03	*	Differences between Families (M=3.4) and singles (3.7) (p = 0.026)
Courtyards	7.022	0.02	*	Post-hoc adjusted p-values indicate no significant pairwise differences Singles (M=3), Couples (M=3.5), Families (M=3.9)

*Note: *Correlation is significant, **Correlation is strongly significant*

A significant difference in overall residential satisfaction was found with post-hoc tests showing that participants living in families (M=4.6) reported significantly higher satisfaction than singles (M=3.7) ($\chi^2 = 11.85$, $p = .003$). When asked whether car-free living has a particular effect on their well-being, families achieved a significantly higher mean score than singles ($\chi^2 = 9.89$, $p = .007$). Families also reported higher satisfaction than singles in sports activities, car sharing and green areas. They also showed greater agreement than couples regarding the mobility station and neighbourhood attachment.

Some differences appeared for perceptions of cycling friendliness, Quality of stay, perception of upkeep and care of neighbourhood, and the perception of courtyards, though post hoc results were not always significant. No significant differences were found for the broader social, contextual, functional, or mobility dimensions.

Qualitative results

Several statements refer to the socio-demographic composition of the neighbourhood and its relevance for residential satisfaction. Respondents often describe a predominance of families with children and point to potential challenges for other demographic groups:

> *„Für Singles oder Leute ohne Kinder nicht geeignet. Dabei möchte ich in einer Gegend ohne Autos wohnen!“ (OEQ-P47, Pos. 19);*
>
> *„Die Siedlung scheint für Familien und Kindern gestaltet zu sein. Oder sie nehmen sich den Raum. Als Erwachsene (mit erwachsenen Kindern) werden unsere Bedürfnisse nicht wahrgenommen.“ (OEQ-P54, Pos. 19);*
>
> *„Als Single ohne Kinder fühle ich mich hier wie ein Alien.“ (OEQ, Pos. 4)*

Expert E1 pointed out that the groups of single parents receive too little attention in the current structure and planning:

> *„Und eine Gruppe, die überhaupt nicht oder so gut wie gar nicht hier unterkommt und die aber sehr autofrei ist, das sind die Gruppe der Alleinerziehenden. Die haben zu 95 Prozent kein Auto bundesweit. Und für diese Gruppe, die eigentlich natürlich hier hinpasste, aus der Beziehung, da haben die ganz wenig Wohnraum, der dafür geeignet ist.“ (E1, line 345-348)*

Another expert addressed the difficulties in accurately predicting the demographic composition during the initial development of the neighbourhood:

> *"Wie gesagt, bei der Erstaufsiedlung haben wir uns total verrechnet, weil die normalen Kennwerte andere sind.“ (E2, line 365-366)*

5.3.2 The impact of age

Quantitative results

Age was grouped into 10-year intervals. Groups with fewer than three respondents were excluded from the analysis. This resulted in an age distribution that is shown in table 12. To investigate these relationships, a series of Kruskal-Wallis tests were conducted, given the non-normal distribution of many variables. No statistically significant difference was found between the age groups in terms of perceived satisfaction ($\chi^2 = 3.78$, df = 5, $p = .581$) and not for other variables either.

Table 12: Number of participants by age group and the respective average satisfaction level

Age (in years)	< 20	30 -39	40 - 49	50 - 59	60 - 69	70 +
n	2	11	28	17	11	13
Mean level of RS per age group	4.5	4.4	4.4	4.6	4.2	3.9
SD	0.7	1	0.8	0.7	0.8	1.3

Qualitative results

The qualitative data shows that older residents sometimes experience restrictions in everyday life and do not feel that they are sufficiently taken into account. One resident sums it up: „*Die Lenbenssituation Älterer wird zu wenig berücksichtigt" (OEQ-P62, Pos. 19).*

Moreover, road safety is a recurring theme as already mentioned before. For example, on older couple reported about a dangerous situation they had regarding safety:

> *„Wir sind über 70 und wären einige Male fast von Radfahrern oder solchen mit Lastenrädern umgefahren worden." (OEQ-P43, Pos. 4)*

Restrictions on mobility in the event of illness are also experienced as problematic, particularly by older people, as reported by a 70-year-old resident:

> *„Im Krankheitsfall dürfen Taxis nicht in die Siedlung -Ausgrenzung von älteren, temporär physisch schwachen Menschen." (OEQ-P72, Pos. 4)*

But also the group of teenagers reported a feeling of exclusion as mentioned by one resident: *"Es gibt nicht so viel für Jugendliche" (OEQ-P69, Pos. 15).*

The expert emphasised the importance of multigenerational spaces and that more attention should be paid to age-appropriate housing and intergenerational neighbourhoods:

> *„Eigentlich will man ja auch Räume schaffen, wo auch mehrere Generationen leben können, weil man merkt ja auch immer mehr, dass es wichtiger ist, dass man Generationen miteinander vereint und nicht nur einen Bereich hat, wo junge Menschen wohnen, die Kinder haben, und dann sind die Kinder groß und dann ziehen die weg. Sondern dass man das auch schon/ und da zieht da die nächste junge Familie hin, das wird in gewisser Weise manchmal nie zu verhindern sein, aber ich merke immer mehr, dass man auch einfach mehr diese Generation wieder miteinander zusammenbringen will, auch wenn das natürlich Verständnis gegenseitig bedeutet.“ (E3, line 398-405)*

5.3.3 Influence of Income

This section examines how income levels affect perceptions of residential quality and satisfaction, combining quantitative data with qualitative insights to highlight potential disparities.

Quantitative Results

To examine whether residential satisfaction differs across income groups, a Kruskal-Wallis test was conducted. All groups consisting of fewer than 3 participants were excluded. The result showed no statistically significant difference between the income groups and the perception of satisfaction (χ^2 (5) = 9.21, p = .1). An overview of the statistics can be found in Table 13.

Table 13: Number of participants by income group and the respective average satisfaction level

Income	*< 250 €*	*1000 € - <1500 €*	*1500 € - <2000 €*	*2000 € - < 3000 €*	*3000 € - < 4000 €*	*4000 € - <5000 €*	*> 5000 €*	*No comment*	*NA*
n	1	1	3	9	21	10	22	18	3
Mean level of RS	4	5	3	4	4.2	4.5	4.7	4.3	4
SD	/	/	2	1	1	0.8	0.6	0.8	1

Note: no comment was actively selected, NA means answer was skipped

Qualitative

The inductive category of '*financial aspects'* include all perceptions and assessments of residents that deal with financial aspects such as the amount of rent. The major issue raised is the lack of affordable housing in the area, with rents and property prices being very high:

> *„Die Mieten sind ziemlich teuer" (OEQ-25, Pos. 17); „Konkret ist der größte Wermutstropfen die rapide steigende Indexmiete einer ohnehin schon sehr hohen Miete, und das bei einer extrem schlecht organisierten nur profitorientieren Hausverwaltung, die sich sehr wenig kümmert und schlecht erreichbar ist." (OEQ-P53, Pos. 17)*

This is seen as excluding people with lower incomes from being able to live there, which, however, is a general problem of new development areas:

> *„Exklusion von Menschen mit geringerem Einkommen, die Mieten sind nicht gerade preiswert. Ein Problem, das aber generell Neubaugebiete betrifft." (OEQ-P36, Pos. 19)*

Expert E2 confirms this perception and emphasises that these expensive rents are generally a problem:

> *„Wir haben ein bisschen das Problem, was die Mieten angeht, dass sie so durch die Decke gehen, was die Kaufpreise von Wohnungen angeht." (E2, line 99-100)*

5.3.4 Length of Residence

This section uses quantitative data to examine how length of residence influences residential satisfaction. An overview of the statistics can be found in Table 14. A Kruskal-Wallis test was conducted to ascertain whether residential satisfaction varies according to the duration of residence.

Table 14: Number of participants by length of residence group and the respective average satisfaction level

Length of residence in years	1	2	3	4	5	6	7	8	9	+ 10
n	2	1	6	3	4	4	2	6	1	54
Mean level of RS per age group	4.5	3	4.2	5	4.5	4	2	4	5	4.4
SD	0.7	/	1.3	0	1	0.8	1.4	1.1	/	0.7

The analysis revealed no statistically significant differences between the groups (χ^2 (9) = 12.93, p = .166). Further group comparisons were conducted to investigate whether perceptions of environmental qualities differ by length of residence. No significant differences were found for the contextual (p = .48), functional (p = .40), or spatial index (p = .40). The social index approached significance (p = .06), while a statistically significant difference was found for the mobility index, (χ^2 (9) = 19.21, p = .02), although the pairwise comparisons according to Bonferroni showed no statistical significance.

In the qualitative interviews, the topic of length of residence almost never came up. Only one resident said that they've lived in Stellwerk 60 for more than 14 years, which was reported positively (GI1-R1), and a teenager said that they were born there and really appreciated growing up there (GI4-R1).

5.3.5 Impact of owning a car

The present section undertakes an investigation into the impact of car ownership on residential satisfaction, based solely on quantitative data. To ascertain the extent to which the perceptions of individuals that possess a car differ from those who do not, a group comparison was conducted utilising the Kruskal-Wallis test. The significant group differences are shown in table 15. To achieve this objective, the residents were categorised into four distinct groups: (1) residents who possess a car (n = 16), (2) residents who exclusively use car sharing services (n = 50), (3) residents who neither own a car nor use car sharing services (n = 14) and (4) residents who possess a car and also utilise car sharing services (n = 8).

In addition, the 8 items on traffic satisfaction were summarised to form an index (*traffic satisfaction*). The internal consistency of the traffic satisfaction index can be categorised as high with a Cronbach's alpha of $\alpha = 0.85$ (n = 88). This speaks in favour of a reliable summary of the individual items into a common index value. To identify which specific groups differed, Dunn’s post hoc test with Bonferroni correction was conducted.

Regarding perceived satisfaction significant group differences were found ($\chi^2 = 10.13$, df = 3, p = .01). According to a post-hoc test, the “car sharing only” group showed significantly higher satisfaction (M = 4.5) than the “neither car nor car sharing” group (M = 3.6).

Group differences were also found for the item *satisfaction with alternative mobility* and the *feeling of restriction*, as shown in table 15. No significant group differences were found with regard to satisfaction with the mobility index.

Table 155: Significant Group Differences in Residential Satisfaction and Mobility-Related Perceptions with Bonferroni-Corrected Post-Hoc Tests

Variable	χ^2 (df)	*p*-value	Groups with significant differences (post-hoc)	Post-hoc *p*-value	Mean values of the groups
Overall satisfaction	10.13 (3)	0.02	Group 2 vs. Group 3	0.01	Gr.1 = 4.5; Gr. 2= 4.48; Gr. 3= 3.57; Gr. 4= 4.25
Satisfaction with alternative mobility	14.74 (3)	<0.01	Group 1 vs. Group 2; Group 2 vs. Group 3	0.01 / 0.02	Gr. 1 = 3.93; Gr. 2 = 4.68; Gr. 3 = 4.07; Gr. 4 = 4.25
Traffic satisfaction index	3.12 (3)	0.3	/	/	Gr. 1 = 4.2; Gr. 2 = 4.5; Gr. 3 = 4.4; Gr. 4 = 4.5
Feeling of restriction	21.59 (3)	<0.01	Group 1 vs. Group 2; Group 1 vs. Group 3	<0.001 / 0.001	Gr. 1 = 2.25; Gr. 2 = 1.28; Gr. 3 = 1.14; Gr. 4 = 1.75

Note: Group 1= "car owner"; Group 2= "only Car sharing"; Group3 = 3 "nor car or car sharing", Group 4= "car owner and car sharing".

6 Discussion

In this chapter the main findings of this thesis are interpreted on the basis of the two guiding research questions with the respective hypotheses and critically considered and discussed in relation to the existing literature and contextual factors. Methodological and content-related limitations are also discussed, and implications for future research are provided.

6.1 Determinants of Residential Satisfaction

This chapter discusses and reflects the results in relation to the first research question. In addition, the results are critically embedded in the existing literature. The aim of this chapter is to summarise the key findings and discuss the extent to which different environmental qualities contribute to or limit residential satisfaction. The chapter is structured based on the determinants presented in the conceptual framework (see figure 1 in chapter 2.3.4), starting with the discussion on general satisfaction.

6.1.1 Satisfaction with Living in a Car-Free Neighbourhood

The results show, both quantitatively and qualitatively, that the residents in Stellwerk 60 are very satisfied with their living environment and feel comfortable living in their neighbourhood. The interviews conducted with eleven residents all yielded a high level of satisfaction among them, confirming the quantitative findings with high rankings for general residential satisfaction (mean= 4.3), well-being (mean= 4.2), quality of life (mean= 4) and perceived quality of stay (mean= 4.3), whereby a rating of 5 means highest satisfaction. These results are in line with the current state of research on the topic of residential satisfaction in car free neighbourhoods. Also, Baehler, (2019) and Sommer & Weichert (2015) have observed a high level of satisfaction among residents of different car-free neighbourhoods.

Particularly noteworthy is the response of residents to the question of how much the concept of car-free living itself contributes to their personal satisfaction. Residents gave this a very high rating with a mean value of 4.8 out of 5. Thus, the results show that the car-free nature of Stellwerk 60 plays an important role in the overall perceived satisfaction of residents and is clearly a key factor in the attractiveness of the neighbourhood. These findings support studies that have identified cars as a cause of dissatisfaction and decreased liveability in cities. For example, März et al. (2022) suggest that banning cars from streets leads to more liveable cities, while Leyden (2003) assumes that walkable neighbourhoods have positive aspects.

On the other hand, the high ratings could also be due to the fact that people voluntarily live in car-free Stellwerk 60 and have tended to make a conscious decision in favour of the concept, which means that they are probably positive about the concept anyway. This interpretation is supported by the results of Baehler (2019), who found in his study, which also examined Stellwerk 60, that 90-98% of households actively and voluntarily opt for car-free living. This trend is also evident in Stellwerk 60, as shown by the quantitative survey, in which over 55% of residents cited the car-free design as an explicit reason for their move. This would imply

that in residential areas where people cannot freely choose the car-free concept or where it is implemented subsequently, the level of satisfaction and the positive assessment of the approach may be different.

Despite the high overall satisfaction ratings, however, critical and ambivalent attitudes were also found among residents, which are discussed in more detail in the following chapters. The general dissonance, of a high overall satisfaction despite some points of criticism could be explained, for example, by the fact that the participants may not want to admit to themselves that they are dissatisfied with their living situation and therefore still give a positive overall rating. This phenomenon can be explained by the cognitive dissonance theory (Raab et al., 2010). It could also be due to the fact that the participants have already developed good coping mechanisms to deal well with the critical and challenging aspects which is why they are generally no longer bothered by them (Algorani & Gupta, 2025).

6.1.2 Mobility-Related Qualities and Subjective Perceptions of Restriction

In Stellwerk 60, 72.3% of residents live without their own car, reflecting the apparent acceptance of the car-free concept. However, this emphasises the importance of well-functioning alternative mobility options and the need to understand the factors that influence mobility satisfaction and perceived constraints. The study examined the extent to which residents of Stellwerk 60 feel restricted in their mobility and how they perceive their satisfaction with the various alternative mobility options.

6.1.2.1 The need for a car and the feeling of restriction

The findings in Stellwerk 60 indicate quantitatively that there is hardly a perceived feeling of restriction among the residents. On the 5-point Likert scale, restriction was rated 1.48 on average, with 1 reflecting no perceived restriction. However no statistical correlation could be observed with overall residential satisfaction, contradicting H3. The lack of correlation may be attributed to the relatively small sample size, which limits statistical power, or it may indicate that the perceived restrictions actually play only a minor role in the specific context of Stellwerk 60.

The findings of a low perceived feeling of restriction align with previous studies. Baehler also found that most residents of car-free neighbourhoods do not feel restricted (2019). In his study 77% of respondents disagreed or somewhat disagreed with the statement that they feel limited without their own car. According to Baehler, the lack of a sense of restriction is due to the fact that nearly all households voluntarily live without a car (Baehler, 2019), a trend that

was also demonstrated in Stellwerk 60. However, similar to the overall satisfaction, the feeling of restriction may be different in areas that were originally open to car traffic but were later made car-free, and where residents did not relocate voluntarily. Further research is needed to examine this issue in more detail in areas where people live car-free without a choice.

However, the qualitative interviews revealed a more differentiated picture of the feeling of restriction and rather contradict the quantitative findings. Some residents with special professional or personal needs consider a car to be necessary and express situations in which they do feel restricted. Elderly people in particular criticised the fact that care services or taxis, which are used by elderly or sick residents, are not allowed to enter the estate even in exceptional cases and that it is generally difficult to obtain exemptions even when there is a genuine need. This dissatisfaction among the elderly could also be quantitatively proven: An analysis of the group differences revealed that residents over 70 years of age in particular had the lowest satisfaction rating (mean = 3.9 out of 5) of all age groups, although not significant. These results show that the problem of agism, as addressed in the theoretical background (Chan et al., 2023; Hammond et al., 2024; Phillipson & Grenier, 2021), may also be occurring in Stellwerk 60 and shows that the needs of the elderly group do not appear to have been sufficiently taken into account. It is therefore important to focus more on the needs of all resident groups, especially the elderly, in future car-free projects, so that they too can live in such residential areas without restrictions and without disadvantages. In order to better meet the needs of older people in a car-free neighbourhood, researchers have already proposed the solution of e.g. allowing small electric cars in the neighbourhood that can be used by older people without major disadvantages for others (Borges & and Goldner, 2015). However, more research is needed to find good solutions for an adopted infrastructure in car-free neighbourhoods to include older people.

Additionally, one resident cited the commute to work as a reason for needing a car to not feel restricted. They report that the journey by bike is too far and would take far too long with public transport (GI2-R5). On the other hand, someone else emphasised that the bike was sufficient for their needs (GI2-R2). This emphasises individual mobility needs and subjective feelings of restrictions as well as demonstrating the need for a multimodal mobility offer in car-free residential areas, including a well-developed public transport system which is discussed in more detail in the next subchapter. This necessity for a multimodal mobility offer has already been emphasised in previous studies on car-free but also sustainable urban

development in general (Kramarz & Przybylska, 2021; Ortegon-Sanchez & Popan, 2016; H. Zhou et al., 2023).

At the same time, the results also reaffirm urban developing concepts such as compact city or more specific 15-minute city, which both aim to ensure that all necessary functions and everyday needs, including work, are close to home, thus avoiding long journeys and making it possible to walk or cycle and eliminating the need for a car (Bocca, 2021; Dreher & Gaspers, 2024).

To sum up, the findings indicate that hypothesis H3, stating perceived mobility restrictions are negatively associated with satisfaction, cannot be confirmed in quantitative terms. However, qualitative data contradicts this finding and indicates groups of people who feel restricted, especially the elderly (70+) and people who have a long journey to work. In order to avoid restrictions, it would therefore make sense to ensure short distances for all functions, whereby the concept of the 15-minute city also comes into play. Additionally, implementing a wide range of mobility options seems to be important, which will be discussed in more detail in the next subchapter.

6.1.2.2 Satisfaction with alternative mobility options

Building on the previous section, this subchapter examines and discusses the insights from Stellwerk 60 regarding the existing mobility offer. Overall, the residents of Stellwerk 60 rate the mobility dimension as very positive, with an average score of 4.5 out of 5. This mobility index also has a statistically significant positive correlation with residential satisfaction (ρ = .25), albeit weakly. This indicates that a higher perception of mobility tends to be associated with higher levels of satisfaction, supporting and confirming the first hypothesis H1, stating that perceived environmental quality correlates significantly with residential satisfaction. It also confirms the assumption made in the theoretical framework that mobility is an important explanatory dimension of satisfaction in a car-free context.

In addition, the individually asked variable on satisfaction with the available alternative mobility solutions was rated very positively by the residents (mean= 4.4 out of 5). A correlation was also observed between the satisfaction with alternative mobility and overall satisfaction (r=0.3), further supporting H1. The fact that the alternative mobility offers of Stellwerk 60 are perceived as good is also shown by the fact that all existing forms of mobility are among the highest rated variables of all measured environmental qualities.

These findings are in line with previous studies, which already emphasised that high levels of satisfaction in car-free neighbourhoods are often linked to the successful development of alternative mobility strategies (e.g. Scheurer, 2001; Baehler, 2019). The available alternative mobilities in Stellwerk 60 include a neighbourhood garage ('*Quartiersgarage*'), cycling infrastructure, a mobility station, car sharing stations and connections to public transport.

A key finding from the Stellwerk 60 case is that a high level of residential satisfaction in the Stellwerk 60 district depends on well-integrated multimodal mobility and not on a single substitute for the private car. This also confirms the discussion in the previous chapter, where the importance of multimodal mobility as a prerequisite for not needing a car was already established (Kramarz & Przybylska, 2021; Ortegon-Sanchez & Popan, 2016; H. Zhou et al., 2023). The data clearly shows that residents value and need a range of options: short distances can easily be covered on foot or by bike, car sharing is needed for flexible or longer distances, and well-functioning public transport is required for routes that would be too long by bike. This is supported by the fact that all individual mobility alternatives correlate significantly with satisfaction and by corresponding statements from the experts:

> *„wir machen mittlerweile bei allen städtebaulichen Aufsiedlungen sogenannte Mobilitätskonzepte, die genau darlegen sollen, welche Maßnahmen wie Carsharing Plätze, vermehrte Fahrradabstellplätze mit Qualität, also mit Überdachung, lasten-Fahrradabstellplätze, Mietertickets. Andere Sharing Systeme neben auto sharing Systeme halt auch Verleihsysteme von Fahrrädern, von Lastenrädern, von Scootern, eventuell auch Mobilitätsmanagement. Die verankern wir mittlerweile in jeglichen städtebaulichen Entwicklungen, damit die Bewohner halt auch eine Möglichkeit bekommen, möglichst auch ohne Auto in einer Stadt leben zu können." (E3 line Pos. 299-308)*

Spickermann et al. (2014) highlight that the integration of individual and public transport systems is not only desirable but essential for future urban mobility. Their research underlines that multimodal mobility will become indispensable for the accessibility of urban centres and that its attractiveness will largely depend on the quality and reliability of the mobility services offered (Spickermann et al., 2014).

In Stellwerk 60, the various existing alternative mobility solutions already appear to be working well, as the quantitative data shows. Also, other car-free neighbourhoods rely on similar alternative mobility solutions. The GWL, for example, a car-free residential area in Amsterdam, offers car sharing options, walking and cycling paths, buses, and streetcar stations on the edge of the estate (GWL Terrein, o. J.; GWL Karte, o. J.). The GWL also

offers separate loading and unloading areas for delivery services and removals, which is still lacking in Stellwerk 60 and was requested by some residents.

The highest satisfaction score was observed for the existing bicycle friendliness in the district (M=4.8). Also, the perceived bicycle friendliness correlates statistically significantly and positively with overall satisfaction, further confirming H1. The importance of cycling as an alternative in car-free neighbourhoods has also been recognised in previous studies (Baehler, 2019; Scheurer, 2001). However, qualitative data also revealed critical statements. Residents complained about the safety risks caused by speeding cyclists, including those on cargo bikes. According to residents, cyclists do not show sufficient consideration for pedestrians and particularly vulnerable groups. Residentes stated: *„Fahrradfahrer*innen mitunter zu schnell und nehmen dann wenig Rücksicht auf den Fußverkehr.“ (*EQ-P1, Pos. 15). This finding is consistent with the result of Marcheschi et al. (2022), who also found in their study that the interviewees wanted a clear separation between pedestrians and other means of transport (e.g. bicycles, electric scooters). In turn, another study could actually show that a clearly separated traffic route for cyclists and pedestrians can increase perceived safety and reduce conflicts (Gössling & McRae, 2022). Thus, future projects should consider separating cyclists and pedestrians more clearly within the residential area.

The perception of the car sharing services revealed a positive assessment by residents (mean=4.14), although no significant correlation was found with satisfaction, contradicting H1. One explanation for the missing correlation could be that this form of mobility does not play a major role for the residents. However, 66% of participants stated that they use the car sharing service, which indicates that this topic is rather important. However, as the survey only asked about use and not frequency, it could be that car sharing is only used rarely or depending on the situation and therefore does not play a major role. This could also be supported by findings from literature. A study by Caulfield and Kehoe found that car sharing options were mainly used for longer distance trips (Caulfield & Kehoe, 2021), which may not happen often in a city where everything is relatively close by. According to another study, people with an environmentally friendly attitude are less likely to use car sharing and are more likely to opt for environmentally friendly alternatives such as cycling and walking (Aguilera-García et al., 2022). This would also be in line with the results of the high level of satisfaction with bicycle friendliness. Regardless of how often residents use car sharing, they generally seem to like the current sharing options, even if not significantly related to overall satisfaction.

In contrast, the lowest level of satisfaction (M = 4.05) was found for public transport as well as a statistically significant negative correlation with residential satisfaction (r = –0.21, p = 0.045). Unexpectedly, this would mean that the more positively public transport is perceived, the lower the residential satisfaction would be. However, the weak correlation coefficient (r = -0.21) and the p-value close to the significance threshold (p = .045) may also indicate that this result was obtained by chance, especially given the relatively small sample size (e.g. N < 100). Alternatively, it may also be that the correlation is not causal, but is influenced by a third factor, e.g. that residents with a high level of overall satisfaction are more likely to use bicycles, car sharing or walking and that public transport does not play an important role for them.

The qualitative data further indicates the worse rating of local public transport by experts and residents. Residents frequently described the public transport network as unreliable, particularly for longer distances, citing delays, cancellations, and poor connections (Group 2-R1, Pos. 61-64). But especially people without a car are dependent on reliable alternatives, which highlights a lack of transport justice (Bruzzone et al., 2023). However, this issue illustrates an important limitation of the urban infrastructure that lies outside the direct influence of the car-free design of the neighbourhood, which emphasizes the importance of integrative urban planning. The environmental program of the UN has emphasized that: ’Integrated planning is a powerful tool to ensure environmentally sensitive and just urban development. Sustainable and integrated urban design is a holistic approach that creates synergies by combining various aspects of city design and management, such as place-making, transportation, housing, health and biodiversity’ (UNEP, 2017, para.2).

The challenge for future car-free developments is to maintain and expand the multimodal offer in a demand-oriented and socially inclusive manner and to ensure a safe, reliable and accessible transport system for all life situations. In order to achieve this, the experts recommend the use of mobility managers who ensure and organize the functioning combination and maintenance of the various mobility solutions, as is already the case in Stellwerk 60:

> *“...diese Aufgabe, dass wir da Mobilitätsberater brauchen. Dass wir immer wieder Menschen immer wieder jemanden haben müssen, also immer einen haben müssen, der immer wieder die Menschen animiert, auf ihre Fragestellung bezüglich des Mobilitätsverhaltens Nachzusteuern, weil man oft so sieht, dann werden da irgendwelche Lastenfahrräder gefördert, die sehen dann am Anfang noch sehr schön aus, dann werden die auch genutzt und irgendwann werden sie nicht mehr genutzt und*

stehen in der Ecke rum. Das hat ja bestimmte Gründe, warum das so ist. Und um solche Dinge dann zu ermitteln, ist so ein Mobilitätsmanager in so einem Quartier sehr wichtig, der dann auf die Leute auch eingeht, der sie vielleicht auch berät. (E3, line 506-514)"

The GWL in Amsterdam has also employed such a mobility manager (sdg21, 2019). However, such a manager alone does not directly ensure transport justice. This requires good planning that is based on the principles of transport justice and ensures that vulnerable groups such as the elderly, children or people with disabilities are not disadvantaged (Martens, 2016).

In summary, the results provide a differentiated answer to the first research question as well as H2. The quantitative data generally shows a high level of satisfaction with the various mobility offers and highlights the importance of bicycle-friendliness in particular. Qualitatively, some elements such as the bicycle garages, the mobility station and car sharing were also positively highlighted. Nevertheless, some qualitative points of criticism were also identified that could limit satisfaction. These include the insecurity of pedestrians compared to cyclists and the unreliability of public transport.

6.1.3 Architectural and urban design as drivers of satisfaction

Spatial qualities encompass residents' perceptions of architectural form, urban planning, green spaces, and the overall accessibility of Stellwerk 60. Although the spatial dimension received a relatively high average satisfaction score of 3.8, it did not correlate significantly with overall residential satisfaction. This suggests that while spatial qualities are valued, they may not be the most important factors for residents' overall satisfaction. It would be possible that once a certain spatial standard is met, other dimensions, such as social or functional aspects, become more crucial, showing that H1 only applies to some environmental dimensions and emphasising the importance of a multidimensional approach and supporting H2. However, qualitative interviews and further in-depth quantitative analyses show a more differentiated picture of the spatial dimension.

Green spaces

Considered individually, green spaces received the highest satisfaction rating within the spatial dimension, but also one of the highest overall (M = 4.11). In addition, when asked which aspects contribute most to their well-being, over half of respondents (51.1 %) cited green spaces as the most important aspect. This is partly confirmed by the qualitative interviews, in which residents praised the large green spaces and the communal garden as

well as the berry patch and described the neighbourhood as a '*green oasis in the middle of the city' (GI2-R3, line 8)*. These results are consistent with other studies where the positive effect of green spaces on people has been indicated as well (Haq, 2011; Naumann & Nadler, 2023; Nieuwenhuijsen, 2021).

Nevertheless, green spaces do not correlate statistically significantly with satisfaction, contradicting H1. The reasons for this can be very diverse. One plausible reason could be the differentiated needs of the residents and that not everyone uses or values the green spaces in the same way, as can be concluded from the ambivalent statements from the qualitative interviews, which supports H4.

For example, on the one hand families praise the benefits of green spaces for children as they can play there safely and freely and move around without traffic. An expert confirms this observation, saying that he has found that the entire outdoor area of the neighbourhood is simply a playground for children (E2). This finding is consistent with previous studies that have also shown that car-free neighbourhood designs increase safety for children (Scheurer, 2001), that children in car-free neighbourhoods are allowed to play outside unsupervised at a younger age (Nützel, 1993) and that this family-friendly environment increases parental satisfaction (Baehler, 2019). On the other hand, there were other residents, especially childless and older people, but also families who strongly criticized the green spaces due to the noise generated by the intensive use by residents, especially by noisy children and the use of the sports facilities (table tennis and soccer pitch). Some residents have even claimed that due to the noise pollution they are no longer able to use the green spaces themselves even though they would like to, which could be interpreted as a sign of dissatisfaction. This perceived noise contrasts with the literature's description of the advantage of car-free settlements as being quieter (Melia, 2014). There is more discussion of this point in chapter 6.1.6, dealing in particular with noise pollution.

There was also criticism of the existing greenery, which is not yet sufficient, especially in terms of heat protection where the neighbourhood green mainly lacks shady trees. Several residents particularly criticized the lack of shady areas near playgrounds and the kiosk and called for more greenery on the facades and additional trees and shrubs to improve shading, reduce the urban heat, and improve the aesthetics of the neighbourhood garage, for example. Urban green is actually very important in the context of climate-friendly and climate-resilient urban planning. Adaptation to climate change is becoming increasingly important for cities in

particular (IPCC, 2024). Urban greenery can greatly help to improve the microclimate through the cooling effects of shade and evapotranspiration (Deigele et al., 2024)

Overall, the green spaces, even though they received a relatively high overall rating, do not show a direct correlation with satisfaction and thus contradict hypothesis H1. In addition, despite the high quantitative rating, some qualitative points of criticism became clear, mainly concerning noise, usability and the need for more greenery, especially for more shade and a better microclimate. Future planning should focus on increasing the density of vegetation, which is also generally more in line with a sustainable, climate-resilient city and providing more multifunctional communal areas to create a balance between tranquillity and social activation.

Design of the public-spaces

Satisfaction with the design of the public spaces was measured with 2 variables, both of which had lower values than satisfaction with green spaces. Satisfaction with the general design of the public space was given an average score of 3.9 out of 5 and satisfaction with the general architecture and design of the buildings was given a score of 3.4, neither of which was found to be significantly related to overall satisfaction, contradicting H1. The lack of significance could indicate that the design aspects are perceived as less important than other factors in regard to overall satisfaction, or it could indicate that the perception of the spatial conditions is very subjective and varies from resident to resident. The lack of significance could also be due to the points of criticism mentioned by the residents, which inhibit satisfaction and are discussed below.

Some residents, for example, expressed their overall disappointment with the architectural appearance. They criticized monotonous facades, a lack of aesthetic variety, and the materials used. One resident described the buildings as “architecturally ugly” and called for more natural materials and colours, such as wood and greenery, to be used to create a warmer and more distinctive environment (e.g. GI3-R2). In fact, research has already repeatedly observed the positive effect of wood as a building material on both aesthetic perception and wellbeing (Rice et al., 2006; Schwinn & Krieg, 2017). In the study by Rice et al., for example, wood was described as ‘cosy’, ‘relaxing’, “natural” and "inviting" (Rice et al., 2006, S. 658). In addition, incorporating wooden elements into urban planning can help reduce feelings of

stress and anxiety, as well as promoting psychological and physiological well-being (Kaplan & Kaplan, 1989; Ulrich, 1981; Ulrich et al., 1991). The preference for natural design is explained by the biophilia theory, which suggests that humans have an innate affinity for nature through living in natural environments (Wilson, 2007). In addition to the positive psychological effects, the positive ecological aspects of wood in construction have also been emphasised. One study found that buildings constructed from solid wood had 81-94% lower global warming potential than concrete buildings and 76-91% lower global warming potential than steel buildings (V. Kumar et al., 2024). Future projects should therefore consider using more wood in the construction of buildings due to the positive psychological and ecological benefits observed.

A further point of criticism was that the neighbourhood is perceived as too small and that residents would like a larger, completely car-free area. This contradicts the arguments of Naumann and Nadler, who claim that the size of a new neighbourhood should be rather small to be manageable so that residents can identify with their new home (Naumann & Nadler, 2023). Yet it is not clear what they mean by a manageable size. Regardless of the actual definition of that size, following these findings, it could be possible that residents misjudge the impact of neighbourhood size, thinking that a larger area would be better and more positive, a phenomenon known as the ‘affective forecasting error’: a theory in which the prediction of future emotions often leads to an over- or underestimation of their duration and intensity (Celestine, 2025). On the other hand, the assessment by residents could be correct, and a larger area could actually lead to greater satisfaction because there is even more space to use, more safe place to stay, more space for green areas, or social equalisation. There is a need for further research in order to be able to assess what size is particularly useful for car-free neighbourhoods and is well accepted in order to give the residents enough space on the one hand, but on the other hand not to be too large so that the area remains manageable, e.g. for maintenance, as well as remaining a place that creates identification and neighbourhood attachment among the residents.

Moreover, the size of the apartments itself was also criticized. Many respondents stated that the apartments were not spacious enough or not well tailored to the needs of families. The lack of larger apartments with four to five rooms was perceived as a major restriction. Since this aspect was only assessed qualitatively, no correlation with satisfaction could be examined. However, Naumann and Nadler consider satisfaction with one's own home to be one of the most important factors for overall satisfaction in new residential areas (2023). One

expert explained that he sees the reason for the flats being too small due to the investors, who did not plan the flats for families but rather for couples without children or at most one child, as these bring in more money:

> *„Die Wohnungen sind natürlich von den Investoren geplant worden auf die Wohnungsgrößen und die entsprechen nur zum Teil diesem Bild. Also man sieht zum Beispiel die größten Wohnungen, also wenn jemand hier mit drei Kindern, dann hat man schon eine Obergrenze erreicht. Also wenn jemand, wir hatten auch Fälle mit fünf Kindern oder so, das ist dann schon, bei den Häusern geht es natürlich, in so einem Haus kriegt man fünf unter. Aber bei den Wohnungen, das ist nicht deren Klientel gewesen. Die haben irgendwie so eine Ein-, Zwei-Kind-Familie mit gutem Einkommen. Das ist so deren Klientel […] Also die Wohnungen von den Investoren, die sind mehr geschäftsgewinnorientiert bedacht." (E1, line 337- 349*)

This conflict between private profit and public interest in the creation of the built environment has also been reported in the literature (Pacione, 2013; Szczech-Pietkiewicz, 2016). Urban planning should therefore better harmonise the economic objectives of investors with public interests. This also requires further studies to identify instruments that cities can use to ensure more demand-oriented housing offers.

In summary, the results show specific points of criticism that lead to dissatisfaction in the spatial dimension, particularly regarding architectural design, apartment size and the limited size of the car-free area. This directly addresses the first research question, as it shows that not all spatial qualities are perceived equally. The results also support hypothesis H2 and confirm that different environmental qualities contribute to satisfaction to varying degrees.

Accessibility and organizational Aspects

Another quality of the spatial dimension is the connectivity and accessibility of the neighbourhood, which is, according to the literature, particularly essential for car-free neighbourhoods (Blechschmidt, 2016; Christ & Loose, 2001). As quantitative data shows, the location of Stellwerk 60 is rated very good by the residents. The general accessibility in Stellwerk 60 was rated very good on average (M = 4.51) and the connection to the city centre was rated similarly good (M = 4.52). The fact that many residents (59%) cited the location of Stellwerk 60 as the reason for their motivation to live there also suggests that Stellwerk 60 has a particularly good location. The experts also confirm that Stellwerk 60 benefits from an advantageous location close to the centre (E2 & E3).

However, no significant correlations were found between the items on location and accessibility and general satisfaction, which would mean that a better connection does not

necessarily lead to more satisfaction, contradicting H1. This could possibly be explained by the fact that in well-connected neighbourhoods, as seems to be the case in Stellwerk 60, the basic needs for accessibility are already met and the residents' assessment of the location is therefore positive, but an even better connection would not measurably increase satisfaction any further. This phenomenon is based on economic principles such as the law of diminishing marginal utility (LDMU) (Kenton, 2025) or psychological mechanisms such as hedonic adaptation, which describes the habituation to a stimulus, which ensures that what was originally observed as positive or negative is at some point perceived as neutral (Armenta et al., 2014).

Yet, another explanation could be that the feeling of accessibility and centrality is subjective and is perceived differently, as the needs are different, which could also be indicated by the moderate dispersion value as qualitative interviews have indicated. Residents have emphasised that accessibility for them is dependent on different needs, especially on the location of the workplace. In the literature it was found that longer commuting times are indeed associated with lower work and leisure satisfaction, higher stress and poorer mental health, but not with lower overall life satisfaction. On the other hand, being able to walk to work is associated with higher levels of leisure satisfaction and lower levels of stress (Clark et al., 2020; Mouratidis, 2019). These results are supported by the concept of the 15-minute city, which, as described above, pursues the goal of having all necessary places, including work, close to home in order to ensure a city worth living in and that increases satisfaction (Bocca, 2021; Dreher & Gaspers, 2024).

In summary, the proximity and connection to the neighbourhood is perceived as very good but lacks a correlation with general satisfaction. However, this does not mean that the location does not play a role, it rather indicates that the location is subjective and that everyone has different connection needs or that the location, once it is good anyway, cannot change much in terms of overall satisfaction.

6.1.4 The Role of Social Qualities in shaping Residential Satisfaction

The social dimension was measured with a direct variable and an index, both of which were rated equally positively (M = 3.9) and showed moderate to strong correlations with residential satisfaction. Thus, H1 is confirmed, and the results show that the social component plays a role in terms of resident satisfaction, supporting previous research, which reports that

walkable and traffic-calmed areas can promote social interaction, familiarity and community cohesion (Leyden, 2003; Nieuwenhuijsen & Khreis, 2016; Rogers et al., 2025).

In addition, 59% of residents stated that it is easier to make social contacts in Stellwerk 60 than in other neighbourhoods, and none of them rated this as more difficult. Reasons for this were not given in qualitative terms. However, explanations could be the neighbourhood events and the working groups of the neighbourhood association. According to the member of the local association (E1), Stellwerk 60 benefits from a high level of civic engagement and a rich offering of initiatives. He pointed out that the existing working groups are diverse and address various topics such as mobility, climate, energy supply, and urban gardening. This is also confirmed by the quantitative data, in which 81% of participants confirmed that there are enough neighbourhood activities. These findings align with findings from Ornetzeder et al. (2008), who showed that residents of car-free housing projects are often highly involved in community life and organise events that contribute to local identity and cohesion (Ornetzeder et al., 2008).

However, some respondents point out that these activities and working groups are often not suitable for all demographic groups and that there are almost exclusively activities for families and children. This reflects critiques raised in the literature, which stress that car-free design alone does not guarantee inclusion. Social spaces must be intentionally designed to accommodate a wide range of users and social habits (e.g. Marcheschi et al., 2022). According to the member of the resident association (E1), however, anyone in the neighbourhood can actually set up working groups, for which an extra meeting room is available. The neighbourhood activities are designed for people to show ideas and initiatives and take care of the groups themselves. This would suggest that this exclusion is more a perceived exclusion than an actual exclusion. However, such perceived exclusion can also have many negative consequences for individuals (Böger et al., 2017). In order to achieve greater inclusion of previously underrepresented groups, it could therefore be helpful to strengthen participation from the bottom up.

The most positive result in the social dimension was found for perceived safety, which was rated particularly highly ($M = 4.7$), also showing a moderate correlation with satisfaction ($r = 0.40$), which suggests that security is an important component of satisfaction. This finding is supported by other studies that have also found that car-free living can create a sense of safety (Baehler, 2019; England & Eriksson, 2020). In addition, the results support the importance of

the aspect of safety in urban planning established in the literature (Ntakana et al., 2022; Sinkienė et al., 2012).

Overall, it can be said that the social qualities of the neighbourhood are seen as good and are linked to satisfaction. However, not all groups feel equally addressed, and some even excluded, which supports H4. Measures are needed to strengthen participation and co-determination, especially for previously underrepresented groups.

6.1.5 Functional qualities and its contribution to residential satisfaction

The functional aspects of the neighbourhood were rated the weakest among all dimensions (M = 3.29) and showed a significant correlation with residential satisfaction, albeit weakly (r = 0.21, $p = 0.048$). This generally supports hypothesis H1. However, the low effect size suggests that functional aspects are not among the decisive drivers of overall satisfaction but rather play a complementary role. The qualitative analyses make it clear that perceptions depend heavily on individual needs and life phases, which qualitatively supports hypothesis H4, according to which functional satisfaction depends heavily on socio-demographic characteristics.

Families in particular seem to benefit from a child-friendly infrastructure, which offers playgrounds, kindergarten and child-friendly neighbourhood events. Older and childless households perceive deficits, which speaks for unjust and exclusionary planning. In particular, mainly childless, singles and young people (but also some families) criticise the lack of leisure and more diverse sport activities and express a desire for facilities such as cafés or volleyball and basketball courts. Older people criticised the lack of support and care services. A lack of offers for certain groups can lead to a feeling of exclusion, as the findings indicate. Being able to fulfil all necessary functions and needs in the vicinity relates again to the concept of the 15-minute city (Allam et al., 2022; J. Chen et al., 2023; Krauze-Maślankowska & Maślankowski, 2025).

In comparison with other international examples of car-free neighbourhoods, it can be noticed that most other areas actually offer more functions in their neighbourhoods. For example the '*Greencity areal*' in Zurich also features a kindergarten but in addition to that a bakery, a café, a supermarket, a hotel, a school and a training centre (Greencity Zürich, o. J.). The GWL in Amsterdam offers a cafe-restaurant (GWL Karte, o. J.) and the Vauban district in Freiburg also provides a market square, restaurants, bistros, cafés and a sports hall (Quartier Vauban, o. J.). However, no study has been found that has investigated the influence of these facilities

on satisfaction. With more functional facilities such as cafés and restaurants, there is also the risk that these will produce a certain amount of noise, which could be perceived as disturbing by some residents (Asensio et al., 2018). On the other hand, places such as cafés can serve as so called '*Third Places'*, i.e. places where people can meet and socialise away from home and work/school, which in turn is recognised as being able to promote social bonding, strengthen community and improve wellbeing (Ferreira et al., 2021; Zhang et al., 2023). The topic of integrating functional facilities into residential areas is therefore a complex issue and urgently requires further research, especially in the context of car-free residential areas, to determine whether they are more favourable or unfavourable in such neighbourhoods.

A similar situation applies to the functional facilities with supermarkets, which were rated moderately and occasionally criticised for their absence, since there is no supermarket in Stellwerk 60 itself. However, there is a settlement kiosk, which according to residents sells the essentials and appears to fulfil the function of a third place. Most residents seem to accept that there is no supermarket directly on the site, but there are also complaints that the nearest supermarket is considered too far away. This could also be a reason why no significant quantitative correlation was found between satisfaction with supermarkets and general satisfaction. Guzman et al. also found in their study that proximity to grocery stores is particularly important and could have an influence on satisfaction (Guzman et al., 2024).

Overall, the functional quality of the neighbourhood is perceived differently and has a different correlation with satisfaction, especially depending on the resident group, supporting H2 and H4. There seems to be a lack of leisure facilities for adults in particular, as well as supermarkets nearby. In order to increase the satisfaction of the residents, the offers should therefore be diversified and adapted to different life situations, which should be considered more in future planning.

6.1.6 Contextual qualities and its contribution to residential satisfaction

Contextual environmental qualities describe overarching impressions of the neighbourhood, such as cleanliness, pace of life, atmosphere, maintenance, and noise. In Stellwerk 60, this dimension is rated with an average satisfaction value of 3.7, which is better than the functional dimension but worse than the other dimensions. The context index showed a strong positive correlation with residential satisfaction ($r = 0.6$, $p < .001$), which on the one hand supports H1 and on the other hand shows that these context qualities seem to play a central role in connection with satisfaction in Stellwerk 60 despite moderate ratings.

Also, viewed individually, all indicators for spatial qualities (cleanliness, atmosphere and care of the neighbourhood) each received a rather moderate average score of 3.7 out of 5 and each variable showed significant strong correlations with satisfaction, further supporting H1 and the important role of contextual qualities. The moderate ratings could be explained by the fact that the perception is very subjective and individualized, which would be further indicated by the relatively high variance, which were equal to or greater than 1 for all measured context items. These subjective and mixed experiences are also reflected in the qualitative interviews. Some appreciate the village character and the quiet atmosphere, while others find the constant hustle and bustle too much or find the district uninteresting. This area of tension once again highlights the importance of needs-oriented planning and the inclusion of different (socio-demographic) groups.

One of the main issues raised, as already noted in the previous subchapters, is the high level of noise, especially from playing children, communal events, and outdoor use of green areas, perceived by many residents as a serious disturbance. Noise pollution was the most frequently mentioned complaint in the qualitative data, with a total of 49 mentions. Many residents stated that they perceive the neighbourhood as *loud* despite the absence of motorised traffic. These perceptions sharply contrast with claims in the literature that car-free areas are quieter and more peaceful due to the lack of vehicles (Baehler, 2019; Leyden, 2003; Nieuwenhuijsen & Khreis, 2016).

This discrepancy can be explained through what one expert referred to as a perception paradox: "*Ich sage mal so, das ist ein bisschen dem Charakter der Siedlung geschuldet. Man gibt den Bewohnern hier eine sehr ruhige Wohnlage. Das heißt, das Lärmempfinden wird per se heruntergesetzt. Dann ist natürlich jeder Lärm, der entsteht, ist viel stärker störend." (E1, line 197-200).* A similar phenomenon was observed in the study by März (2023), where residents of a low-traffic settlement also perceived a notable increase in noise, particularly from social activities and children playing in shared spaces. This study further suggests that car-free environments do not automatically guarantee acoustic comfort and that the absence of traffic may increase sensitivity to other types of noise, particularly social noise.

This is especially relevant in the context of green spaces, which are usually associated with relaxation and health improving functions (Haq, 2011; Nieuwenhuijsen, 2021). Ironically, in Stellwerk 60, it is precisely the green spaces that are often perceived as sources of noise and discomfort due to children playing, group activities, and social events. This paradox challenges assumptions about green space functions and highlights the need for spatial

designs that balance social activation with noise sensitivity. These differentiated findings support H2.

In addition, a perceived sense of injustice was expressed regarding the noise level. Residents have experienced that there are different noisy places within the neighbourhood: *"Es gibt innerhalb des Viertels ein Gefälle der Wohnqualität. Während es innen beschaulich und ruhig ist, nimmt an den Randstreifen die Unruhe zu."* (OEQ-P79, Pos. 6). This gradient has also been confirmed in the observations and shows once again the importance of fair and needs-oriented planning.

Further criticism concerned the state of maintenance of the public areas, including dog excrement on green spaces, a lack of lighting in the park and repeated illegal dumping of waste. According to the literature, a dirty environment can have a negative impact on health or, according to He et al. (2025), can even lead to a significant increase in depression. It is therefore important to take this criticism seriously and find better maintenance strategies (He et al., 2025; Pratiwi et al., 2024). In response to the problem of e.g. dog waste in shared green spaces, designated dog parks could be a practical solution, such as the car-free neighbourhood of Culdesac Tempe in the US which has a dedicated dog park as part of its spatial concept (Culdesac, 2025). Such design elements could be considered for future car-free developments to reduce conflicts over shared public space and improve overall maintenance and cleanliness. However, the literature shows that conflicts can also arise in dog parks and that well thought-out strategies are therefore needed for the planning and management of dog parks (S. Chen et al., 2022).

Overall, the results confirm that the contextual qualities are all related to satisfaction, supporting H1. The results show, both qualitatively and quantitatively, rather mixed experiences. While some appreciate the village character and find the district quiet, others find the activity and liveliness too much and too loud, and still others find the neighbourhood uninteresting. This area of tension highlights the importance of needs-oriented planning of public space, in which the needs of different socio-demographic groups are taken into account. As in the case of Stellwerk 60, not only the public spaces but also the micro-location of the flats should be considered so that residents who need more peace and quiet are not disturbed by the "noise" of the green area and only those with houses benefit from a quiet location. Other problems such as littering and poor lighting also reveal deficits. These nuanced results support H2 and confirm the research gap of noise pollution in car-free areas, identified in the theory section.

6.2 Further explanatory variables that influence residential satisfaction

In addition to the environmental qualities assessed by the PREQI model, this study analysed additional factors that can affect satisfaction in Stellwerk 60. These include socio-demographic characteristics (e.g. age, household type, income, length of residence), as well as the ownership of a car. The chapter thus addresses research question 2.

6.2.1 The impact of socio-demographic factors on residential satisfaction

Significant group differences were only found for the influencing variable household type, whereas the influencing variables age, income or length of residency did not show any significant group differences when examined quantitatively, which only partially confirms H4. The lack of significant quantitative differences does not imply that socio-demographic factors are irrelevant. Qualitative data shows clear perceived differences between different groups. The reason for the lack of significance of the group differences could therefore lie in the small and overall very differently sized groups. This underlines the value of mixed methods approach as qualitative methods can uncover subjective needs and hidden inequalities that are not captured by standardized instruments.

In terms of household types, it was found both quantitatively and qualitatively that families were significantly more satisfied with their neighbourhood than singles and couples without children. In the interviews, families, which made up 60% of the participants, particularly praised the ideal conditions for children, while childless and single people complained that the neighbourhood was not suitable for them: ‚*Für mich als Singlefrau (32) gibt es hier gar nichts.‘ (OEQ, Pos. 8)*. The observation that car-free neighbourhoods mainly attract families has also been found in other studies. Baehler's research found that 41% of households living in car-free or car-reduced neighbourhoods were families (2019).

However, this is a rather atypical distribution and a very high share of families for an urban context. In contrast, 52% of households in Cologne are single-person households, and only 18% are families (Kölner Statistische Nachrichten, 2025). According to an urban planning expert, this atypical distribution has led to problems in the planning of Stellwerk 60, as the demand for kindergarten places and schools was incorrectly estimated. Precisely because the socio-demographic distribution in car-free areas is different from other urban settings, it is important to pay more attention to this aspect in regard to car-free neighbourhoods in future research.

Although no significant quantitative group differences were found with regard to the age variable, the qualitative and descriptive results showed differentiated findings, as already mentioned in chapter 6.1.2.1 on the feeling of restriction. In quantitative terms, the group difference shows that the over-60 age group is less satisfied than the other age groups, which could also be identified through qualitative statements: '*Die Lebenssituation Älterer wird zu wenig berücksichtigt.'(OEQ-P62, Pos. 19).* This again addresses the potential problem of ageism in Stellwerk 60 (Chan et al., 2023; Hammond et al., 2024; Phillipson & Grenier, 2021). In turn, teenagers have also occasionally complained that there is nothing of interest for them in the neighbourhood: *'Es gibt eigentlich nichts interessantes für Jugendliche.' (OEQ, Pos. 17).* Future planning should aim to create diverse and needs-based spaces that enable both lively social interaction and quiet, age-appropriate retreat areas. Participatory planning processes that involve older adults, for example, could be helpful in ensuring that their voices are not only heard but also translated into spatial decisions.

Overall, the results show that families particularly benefit from the environmental qualities on offer, while those without children, young and older people express restrictions and unfulfilled needs. The combination of the quantitative and qualitative results shows how important it is to consider the different needs of the various population groups in a differentiated manner when planning and designing car-free neighbourhoods in order to ensure the highest possible quality of life and inclusion for all.

6.2.2 Impact of owning a car

Previous literature has already considered that car ownership can also have an impact on satisfaction as well as feelings of limitation (Li et al., 2022; Morris et al., 2020; Saadaoui et al., 2025). In terms of general residential satisfaction, the finding of this study indicates that 'car owners' had the highest mean value (M = 4.5) of satisfaction, while the 'neither car owners nor car sharers' group had the lowest value (M = 4.2), although this is not a significant difference.

The results, that car owners are not significantly more satisfied, could be due to a statistical error, as the group sizes are all quite different, which can lead to measurement errors (Oldfield, 2023). The tendency for residents without a car to be slightly less satisfied, albeit not significantly, would be consistent with the findings of Morris et al. who observed that a lack of a private vehicle can affect quality of life (2020). However, the actual lack of significance may also suggest that car owners are genuinely not more satisfied, which is

consistent with the findings of Lie et al. who found that car ownership was not associated with increased life satisfaction, at least in their case study in Beijing (Li et al., 2022).

Another result is that ‘car sharers’ have a significantly higher level of overall residential satisfaction than the group that is ‘neither a car owner nor a car sharer’ ($p = 0.02$).Similarly, in terms of satisfaction with alternative mobility, the car sharer group also has a significantly higher level of satisfaction than the group that is neither car owner nor car sharer ($p = 0.02$) and the group of ‘car owner’ ($p = 0.01$). This indicates that car sharing appears to be associated with a positive assessment of the living environment and mobility conditions and that car sharing consequently appears to be a crucial element in car-free neighbourhoods.

One reason why car sharers are significantly more satisfied could be because they enjoy the advantages of high mobility flexibility without the disadvantages of owning a car, such as costs and parking problems, as one resident also expressed qualitatively: *“Also ich, für meinen Teil, habe ja zwei Cambio-Stationen zur Auswahl und für das [...], lebe ich echt günstiger, als wenn ich eins hätte.” (GI2-R2, Pos. 59-60).* The literature also suggests that car sharing has a greater cost advantage, at least for middle- and lower-income groups, for short journeys, and can be a more flexible mode of transport (Dong et al., 2020; Hu et al., 2024; Papu Carrone et al., 2020).

Additionally, the results indicate that the group that neither has a car nor uses car sharing feels more restricted and is therefore less satisfied, which would be consistent with the results of Morris et al. who showed that the lack of a private vehicle can affect quality of life (Morris et al., 2020). This would suggest that people need a car in order to not feel restricted, but that it does not matter whether they own or share a car. This would also be supported by the lack of significance in the group difference between the two groups (car owner vs car sharer). However, the group differences in terms of feeling restricted surprisingly show that the car owner group statistically feel the most restricted ($p <0.01$), as well as the least satisfied group with alternative mobility solutions ($p <0.01$).

Thus, the influence of car ownership shows a very contrasting picture. On the one hand, car owners are the most satisfied group, but at the same time they also feel the most restricted and are the most dissatisfied with alternative mobility solutions. One possible reason for this could be that there are car owners who are frustrated by the limited availability of parking spaces, as one resident said:

> *"Zu wenig Stellplätze im Parkhaus. die Hausbesitzer, die einen Stellplatz haben, lachen sich kaputt. die Mietshaus betreiber auch, weil sie sich den Parkplatz gespart haben. 80% der Nachbarn haben ein Auto." (OEQ-P8, Pos. 15)*

Another reason could be that car owners are less dependent on alternatives and use them less, which would explain the lower level of satisfaction in this context. In order to verify this, further studies are necessary, which examine the frequency of use of the users for the different modes of mobility in this context.

It is also possible that former car owners have consciously chosen to live without a car because of other advantages and needs. They have set their priorities and accepted the resulting restrictions, which can be described as a typical trade-off situation, meaning that in order to gain a certain advantage, you have to accept a corresponding disadvantage or give up something else („tradeoff", 2025). For these people, residential satisfaction therefore seems to be determined more by other factors that are advantageous to them, such as location, housing quality or social environment, while functional mobility is viewed critically.

Interestingly, the group 'neither own a car nor use car sharing', feel almost no sense of restriction at all (M = 1.1, where 1 is no feeling of restriction at all), which also reaches significance. This lack of a restricted feeling may indicate that they have specifically opted for a car-free form of living that fits in well with their beliefs, everyday expectations, and routines. Their satisfaction then results less from the variety of options and more from the compatibility of their lifestyle with the built environment.

The results overall indicate that it seems to be important to be able to use a car, despite a car-free environment, but the results suggest that it makes no significant difference whether it is your own car or a shared one. Those with their own car are slightly more satisfied but not significantly and car sharers feel less restricted. Those who consciously live without a car or car sharing are the least restricted. The significant group differences in satisfaction levels confirm hypothesis H4. However, the post hoc test revealed that only a significant difference remained between car sharers and those who neither own a car nor use car sharing services. This further confirms hypothesis 4, particularly for car sharers, and highlights the important role they seem to play. However, further research is needed to deepen understanding and investigate the usage behaviour of residents in order to be able to draw further conclusions about the satisfaction but also the feeling of restriction in car-free areas.

6.3 Critical Reflections and Implications for Future Studies

In this concluding chapter, the methods used are critically reflected upon and the weaknesses and strengths of the work are identified and discussed to derive concrete implications for future research approaches. The mixed method approach is considered first and then the methods are examined individually.

The **mixed-methods** approach was carefully selected to capture the complex nature of residential satisfaction and to gain a comprehensive understanding of residential satisfaction in the car-free Stellwerk 60 neighbourhood. While the quantitative data made it possible to identify significant effects and correlations between environmental qualities and residential satisfaction, the qualitative data provided deeper insights into subjective experiences. In addition, qualitative data revealed topics that were not quantitatively visible, such as experiences with the neighbourhood garage, financial aspects or the influence of age on satisfaction. Qualitative data could also be confirmed quantitatively, e.g. on the topics of the influence of household types, where the advantage of families was clear in both methods, or on the topic of sports and leisure opportunities, where both methods revealed that needs in these areas are not fully met and satisfaction is only moderate. In most cases, the qualitative data complemented the quantitative data and better explained the level of satisfaction, such as in the areas of feeling restricted, architectural planning, noise pollution or safety. Thus, the combination of quantitative survey data with qualitative interviews proved to be effective in validating data on the one hand and revealing deeper and more nuanced insights into the individual perceptions of residents and experts that could not be measured quantitatively on the other.

The **quantitative data** is based on self-reporting by residents, which can be influenced and distorted by subjective perceptions, memory errors, social desirability, or non-response (Grimm, 2010). Although the overall response rate was satisfactory and comprised 88 participants, the number of participants nevertheless limited the statistical significance of the results, especially in the subgroup analyses where a few subgroups were too small to be meaningful, e.g. the group of residents living in a shared flat or those under 19 years of age. One group that did not appear at all is the age group 20-29 years. It is unclear whether this group is generally very underrepresented in Stellwerk 60 or whether it is just strongly underrepresented in the survey. In addition, due to an error, further socio-demographic information such as gender and nationality was not recorded, which limits the contextual classification.

The primarily applied correlation analyses allowed for the identification of significant associations between perceived environmental qualities and residential satisfaction. But they only allow a limited interpretation. Correlations do not provide any information on causalities, nor can it be ruled out that the relationship can be explained by the influence of a third variable (Janse et al., 2021). Additional regression analyses could have helped to verify causality. However, due to time and resource constraints, such analyses could not be conducted within the scope of this thesis. Future studies should therefore use multivariate methods to more accurately determine the unique contribution of specific environmental or individual factors to residential satisfaction. This would allow a more nuanced understanding of their relative importance and interactions and strengthen the robustness of the results.

As already evaluated in chapter 4.4, the survey was based on the established PREQI framework (Bonaiuto et al., 2006; Mao et al., 2015; K. Zhou et al., 2021), which strengthens the quality of the questionnaire. However, the framework has been adapted to better capture the specificities of a car-free neighbourhood. While these changes were necessary to reflect the specifics of the case study, they may affect and limit the comparability of the results with other studies based on the original model. In order to check the quality of the adaptation, pretests were carried out and the internal consistency of the various scales was checked using Cronbach's alpha (Schecker, 2014), which indicated good internal consistency and therefore reliable results.

The **qualitative interviews** with residents and experts provided valuable contextual perspectives but represent only a limited range of voices. Not all population groups within the neighbourhood were equally represented. The qualitative open questions in the questionnaire have the same underrepresented groups as the quantitative survey. The interviews conducted in person were mainly with older adults, primarily belonging to the family household type. Although this group makes up most residents, it was still overrepresented, while other groups, especially older people and singles, remained underrepresented. Future studies should try to address these underrepresented groups even more. Another interesting group that was not directly studied was the group of single parents, which, according to expert E1, should be an important group for car-free neighbourhoods.

In addition, the qualitative expert interviews helped to embed the residents' statements in a larger context. The integrated findings contribute to a nuanced understanding of the relationship between neighbourhood design and resident satisfaction in the car-free development in Cologne. However, they just focused on experiences specific to Cologne,

which was caused by the case study, but this limits the transferability of the results to other urban contexts or planning systems (Queirós et al., 2017). Challenges in recruiting experts arose due to the long time since the project's initiation. Many of the individuals originally involved were no longer available or no longer held relevant positions. Attempts were also made to involve professionals from private companies and engineering firms that contributed to the project. However, none of these experts were available for interviews.

Another challenge, especially with qualitative data general, is the possible subjectivity in the interview evaluation and interpretation, which can arise from the researcher's own professional and cultural background, for example, and can never be completely ruled out (Reichertz, 2015).

A cross-sectional design was used in the study, which does not allow any conclusions to be drawn about temporal developments or causalities (Solem, 2015). The observed correlations between perceived environmental qualities and residential satisfaction can therefore not be assigned a direction. Future studies should therefore also use longitudinal designs to better understand causal relationships and temporal dynamics between perceived environmental qualities and residential satisfaction.

Furthermore, this study only refers to one case study and the sample is not representative, which limits the transferability to other areas. Further research is needed to investigate environmental quality and residential satisfaction in other car-free areas, ideally using comparative or longitudinal designs to capture broader trends and contextual differences.

7 Conclusion

The specific aim of this work was to investigate how environmental qualities are perceived in car-free neighbourhoods and how this influences residential satisfaction. This also included comparing and investigating satisfaction between different groups of residents. The study should also help to close the research gap on residential satisfaction in car-free neighbourhoods and provide practical advice for future urban planning. To achieve this, a case study approach was chosen in combination with a mixed methods approach, mixing survey data from 88 residents with in-depth interviews from 13 residents, additional expert interviews (n = 3) and observations of the subject area. The results provide a differentiated picture of the experiences of residents in Stellwerk 60 and show both the consistently valued features and the perceived shortcomings that lead to satisfaction or dissatisfaction.

With regard to the first research question ‘What perceived qualities of the living environment contribute to residential satisfaction or dissatisfaction in the car-free Stellwerk 60 neighbourhood?’, the results show that residents are generally very satisfied with life in Stellwerk 60. Overall satisfaction with living conditions, quality of life and well-being was consistently rated highly, with average scores above 4 on a 5-point scale (where 5 stands for ‘very satisfied’ and 1 for ‘not at all satisfied’). This positive trend was also reflected in the interviews, in which all participants responded favourably to general satisfaction. However, when analysing the individual satisfaction factors, a more differentiated picture emerged. Among the measured environmental dimensions, contextual, social and functional factors showed significant correlations with overall residential satisfaction, while mobility and spatial indices did not reach significance. A detailed analysis of the individual dimensions and their specific quality indicators revealed further complex results.

The contextual index, i.e. upkeep and care, environmental health, and neighbourhood atmosphere showed the strongest positive associations with residential satisfaction overall, albeit only with a moderately rated satisfaction level. Upkeep and care were rated as the best aspect, while the statement that the neighbourhood is interesting was rated as the worst, both showing significant correlation to satisfaction. Additionally, qualitative data indicated that noise pollution, which is often linked to playgrounds and green areas, is perceived by many as very negative and appears to lead to dissatisfaction.

Although the overall mobility index did not correlate significantly with residential satisfaction, individual elements such as bicycle friendliness, the mobility station and alternative mobility solutions were rated very positively and showed significant correlations with residential satisfaction. In contrast, public transport received the lowest ratings and showed a negative correlation. While perceived mobility restrictions were generally low and not significantly related to satisfaction, the qualitative data showed that certain groups, particularly older residents, may experience restrictions due to a lack of flexible exceptions, such as access to taxis.

The social dimension index had the second-highest level of satisfaction. The individual qualities, social contact opportunities, sense of community and sense of security also correlate positively with general satisfaction. However, the indicators social contact opportunities and sense of community were rated the worst of the social qualities. The qualitative interviews show that the biggest problem is the perceived homogeneity of neighbourhood events, which

mainly appeal to families or older people and neglect other groups, leading to a feeling of exclusion for some.

The functional dimension was rated very moderately but is significantly related to satisfaction. It was qualitatively determined that there is a lack of leisure infrastructure with cafés, restaurants, bars, and sports activities for adults, such as a basketball or volleyball court. Similarly to the social dimension, not all groups seem to be addressed equally, which also causes a feeling of exclusion and dissatisfaction among some residents.

The spatial dimension received neutral ratings overall and showed no significant correlation with residential satisfaction. Within this dimension, accessibility and the location of the living space were rated best, followed by green spaces and the design of the public space. All were perceived positively but showed no significant correlation with satisfaction. Architecture and building design were rated the worst. The lack of green spaces, especially trees, flowers and façade greenery, the monotonous aesthetics of the buildings were criticised and the desire for more colours and natural materials such as wood were raised. Residents also expressed dissatisfaction with the size of the flats and would like to see a clearer separation between cycle and pedestrian paths.

The second research question investigated additional factors that influence residential satisfaction in car-free neighbourhoods and focused on socio-demographic differences and car ownership. The quantitative analysis only confirmed household composition as a significant factor: families reported significantly higher overall satisfaction than singles, as they benefited most from the available infrastructure. Families also expressed greater satisfaction with certain facilities such as sports facilities, the mobility centre, green spaces, playgrounds and leisure areas than singles and couples. Although age was not statistically significant, the qualitative data showed that both younger and older residents felt underserved. Young people criticised the lack of attractive leisure facilities and found the neighbourhood boring, while older residents expressed a feeling of restriction and called for more age-appropriate facilities.

The influence of car ownership has shown very contrasting results. The car owners reported the highest overall satisfaction, but this difference was not statistically significant. However, they also felt significantly more restricted by the car-free living environment. Residents who neither own a car nor use car sharing showed the lowest level of satisfaction. These results indicate that flexible access to a car and not car ownership itself is decisive for satisfaction.

Car sharing offers mobility benefits without the disadvantages of car ownership and therefore appears to be a key factor for residential satisfaction in car-free neighbourhoods.

Building on the results presented above, this study makes a significant contribution by addressing a research gap in understanding residential satisfaction in car-free neighbourhoods and the contributing factors from a comprehensive perspective. Previous studies have mostly focussed on individual aspects such as air pollution, noise pollution or health effects, whereas this study integrates multiple environmental qualities as well as socio-demographic factors. Such a multidimensional approach is particularly valuable in complex environments such as urban environments.

The results not only contribute to a more comprehensive scientific understanding but can also provide practical implications for urban planners and policy makers with regard to future car-free neighbourhoods. The findings reveal that several elements of Stellwerk 60 can already be described as best practice and should therefore also be considered in other neighbourhoods. These include the mobility station, the wide range of multimodal mobility options such as the well-functioning bicycle infrastructure and car sharing, as well as the central location of the neighbourhood, which ensures good connections to the city centre.

At the same time, the study highlights potential for improvements that should be implemented in future car-free neighbourhoods to increase residential satisfaction. For example, public spaces and leisure infrastructure should be more designed to attract a wider range of age groups and lifestyles. This can be enhanced, for example, by providing cafés, bars and adult sports facilities such as basketball or volleyball courts. In addition, the current mobility concepts should be more age-appropriate, e.g. by enabling more exceptions such as allowing taxis for elderly or sick residents to drive into the neighbourhood. Improving the aesthetic design of public spaces could also help to increase satisfaction. This includes, for example, to improve greenery (green facades and additional trees), implement colourful architecture and use natural building materials such as wood. In addition, the cycle and pedestrian paths should be separated to enhance safety and thus also greater satisfaction for both user groups. It is also important to reduce noise pollution, as the results have clearly shown, especially in playgrounds and green spaces. This could be achieved through e.g. spatial zoning, noise-absorbing materials or adapted flat designs, such as installing windows that do not face onto green spaces. These considerations can help to ensure that car-free neighbourhoods are not only ecologically sustainable but also socially inclusive and liveable for different groups.

However, some limitations must also be acknowledged. Firstly, the study focused on a single case, which may limit the generalizability of the results. Secondly, the sample size, especially for the qualitative data, was relatively small and not fully representative, e.g. in terms of age or household types. And thirdly, the study can only determine correlations, not causalities.

To address these limitations, future projects should examine additional car-free neighbourhoods to allow for comparative analyses and broader generalisation. It would also be valuable to focus more explicitly on the perspectives of underrepresented or less satisfied groups, such as young people, older residents or people with mobility impairments, to ensure inclusive planning in the future. Furthermore, additional longitudinal studies would be useful to enable a more differentiated understanding of the temporal dynamics and to better identify causal relationships.

With more future research and careful planning, car-free neighbourhoods have the potential to become a key model for sustainable and satisfying urban living in the future.

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9 Appendix

The appendix is not directly included in this document but is available digitally. The appendix can be accessed at any time via the link below as well as by scanning the QR code:

Link to the Appendix: https://tinyurl.com/ThesisCarfreeliving