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Review

# Driving Towards Car-Independent Neighborhoods in Europe: A Typology and Systematic Literature Review

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**Abstract**
Car-independent neighborhoods can be seen as a planning strategy for overcoming car dependency and achieving urban sustainability goals. This implies a structural and psychological car independency of people, which manifests itself into positive attitudes and perceptions towards sustainable mobility, acceptance of corresponding measures, and a shift from private cars to active transport, public transport, and sharing modes. Despite their relevance, knowledge regarding the actual implications of the various existing strategies remains scarce. This gap is addressed in this literature review, which aims to: (a) identify types of implemented car-independent neighborhood policies; (b) explore their rationales, main characteristics, and implications for mobility behavior, psychological factors, perceptions, and acceptance; and (c) investigate how they have been evaluated. Existing implementations in Europe can be divided into four types: car-independent central areas, residential developments, citywide implementations, and temporary interventions, which differ in their rationales and scope. Overall, little research was found on this topic, with most studies focusing on newly built residential developments, compared to the other types. There is evidence of positive impacts on sustainable mobility behavior in the relevant use cases. However, it is often unclear whether this is a causality or correlation due to the absence of comprehensive (longitudinal) evaluations. Less is known regarding the implications of implementations for psychological factors and perceptions and their interplay with mobility behavior. For future research, it is recommended to evaluate other types of car-independent interventions beyond newly built developments through long-term observation of attitudinal and behavioral changes.

**Keywords**
acceptance; attitudes; car dependency; car-free; car-independent; low-car; mobility behavior; perceptions; review; typology

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## 1. Introduction

The mass motorization, the modernist planning ideal of functional segregation, the consequent planning around cars, and values attributed to the car, such as freedom and flexibility, were each a catalyst in promoting car dependence in the last century, which Urry (2004, p. 27) called the “century of the car.” Early on, urban historians, such as Lewis Mumford, criticized the role that cars would have in destroying the complexity of existing urban fabrics (Ellis, 2005). This realization only grew post World War II, a time in which cities were being rebuilt in a way that allowed cars to flourish. As Jane Jacobs (1961/1992) later emphasized, the unrestricted integration of cars into cities would lead to the degradation of livable, multi-purpose streets and public spaces. Yet, despite critics’ insights, the movement of car dominance proceeded and remains palpable in the function and form of today’s cities as well as in society.

The car-free or car-reduced city can be considered a counter-model to the planning paradigm of the car-oriented city in order to tackle pressing issues such as

pollution, climate change, public health, social injustice, or livability (Glazener & Khreis, 2019; Nieuwenhuijsen et al., 2019). This concept dates back to the 60s and 70s with the first wave of pedestrian zones in central parts of European cities (Nieuwenhuijsen et al., 2019; Orski, 1972). It is worth noting that most European historic centers were originally designed with a primary orientation towards walking, evident in their narrow streets and mixed, compact land uses, and that they had functioned without automobiles prior to the 20th century (Gehl, 2010). Since then, new initiatives such as car-free days and new car-free residential developments have emerged in planning practices, representing a diverse landscape of policies of different scopes, contexts, and intentions (Glazener & Khreis, 2019). Truly car-free cities have so far only existed in exceptional geographic and political contexts, such as Venice or Cuba (Melia et al., 2014). They have therefore remained more of a utopian planning idea, most famously envisioned by Crawford (2000). Current attempts are generally limited to neighborhoods, but can potentially be expanded to the wider city, as demonstrated by Barcelona's superblock concept. The strategy of a car-free or car-reduced neighborhood aims to create an urban setting in which private motorized transport plays a subordinate role. Car parking and access are restricted in combination with pull measures, such as the prioritization of public transport, walking and cycling infrastructure, high local accessibility to daily needs, or the design of streets as social multipurpose spaces. The car-free or car-reduced city or neighborhood concept thus shares common principles with historic planning ideas such as Clarence Perry's neighborhood units, as well as new urbanist concepts, such as transit-oriented development and, more recently, the 15-minute city.

A variety of terms have been used in literature to describe these interventions. The widely employed term car-free can generally be understood as the exclusion of motorized vehicles (in defined areas; Melia et al., 2010; Morris et al., 2009; Orski, 1972). Arguably, a certain level of motorized transport, including public transport, emergency and logistics vehicles, as well as private cars for mobility-impaired people, needs to be maintained, making the term somewhat misleading (Topp & Pharoah, 1994). To account for less restricting policies, various authors refer to car-reduced or low-car developments (Melia et al., 2010; Morris et al., 2009; Selzer & Lanzendorf, 2022). Whereas Delbosc and Currie (2012) label households with up to one car per household as low-car, Brown (2017) distinguishes between people who do not possess a car by choice (car-free) or involuntarily (car-less). These terms have also been used in an effort to classify the various manifestations into typologies based on their car restrictiveness (e.g., Melia et al., 2010; Morris et al., 2009). Wright (2005) proposed a car-free matrix that classified cases along two axes of spatial and temporal scale ranging from car-lite measures to large-scale car-free implementations.

To avoid these ambiguities, we adopt car independency as the umbrella term for this article and define it as follows: Car independency describes the ability to live without being reliant on private motorized transport ownership and use. Consequently, car-independent cities or neighborhoods are planned in such a manner that people mainly rely on sustainable mobility options to fulfill their mobility needs. This implies reversing the actual structural, as well as the perceived or psychological, car dependency of people (Lucas, 2009). While car-free or car-reduced developments structurally improve conditions for car-independent behavior, it can be argued that due to psychological factors, such as strong positive attitudes towards car use and ownership, these developments do not necessarily lead to the acceptance of the respective policies and the (immediate) adoption of sustainable mobility behavior. Moreover, people tend to choose a residence that matches their mobility preferences (so-called residential self-selection) or, if that is not possible, to live in their current neighborhood in dissonance with their attitudes (De Vos et al., 2012). Conversely, the residential neighborhood can change travel attitudes and behavior (De Vos et al., 2018). These general interactions between travel behavior and the built environment, residential self-selection, and psychological constructs, such as norms, preferences, and attitudes, have been covered extensively by mobility behavior studies (e.g., Cao et al., 2009; Ewing & Cervero, 2010; Handy et al., 2005; Steg, 2005). It nonetheless seemed of interest to examine whether real-world car-independent neighborhood interventions in specific have been analyzed in these regards to determine their potential for sustainable urban mobility. Furthermore, perceptions and acceptance are typically studied to measure the adoption of technological innovation into society (Huijts et al., 2012), which in this case can help to understand the success of car-independent policies. As Loo (2018, p. 7) argued, "the underlying perceptions and values of individual local residents are critical in understanding and sustaining the success of the car-free zone."

Thus far, substantial knowledge has been gathered on the potential environmental, social, and health benefits of car-independent cities (Nieuwenhuijsen & Khreis, 2016) as well as on the barriers and drivers of the transition (Nieuwenhuijsen et al., 2019). Melia et al. (2010) examined some of the early findings of the 2000s regarding the impact on mobility, social benefits, and issues of new car-reduced residential settlements. More recently, Sprei et al. (2020) reviewed the mobility effects of mainly Swedish housing projects as well as the evaluation quality of corresponding studies. Other types of car-reducing implementations, specifically those changing existing structures and temporary interventions, have not been adequately addressed by previous reviews. This review will expand on previous research by looking at all types of car-independent implementations beyond newly developed areas and adding the perspective of

attitudes, perceptions, and acceptance beyond mobility behavior. Secondly, it will address both the methods and scientific rigor used in existing studies to derive recommendations and research directions for the evaluation of car-independent developments. Specifically, this article wants to shed light on the following research questions: Which types of car-independent city interventions have been implemented, and what are their rationales and main characteristics? How have they been evaluated in terms of mobility behavior, attitudes, perceptions, and acceptance? Our focus is on European cities as they are still the forerunner in implementing car-independent areas compared to the rest of the world (Bartzokas-Tsiompras, 2022) and literature is mainly available in this context. We further excluded historically car-free cities such as Venice to be able to address the change towards car-independent cities. Hereafter, Section 2 describes the methodology, and Section 3 reports the evidence found using the developed typology. In Section 4, conclusions on the findings are drawn and are followed by an outlook in Section 5.

## 2. Methodology

The methodology begins by conducting an initial screening to categorize various car-independent neighborhood interventions into four distinct types. For each type, the temporal and spatial scope, as well as the rationale and examples, are described. Afterward, a systematic literature review is conducted, using selected keywords concerning car independency, and each included study is assigned to a type for further analysis within each cluster.

### *2.1. Typology*

As a preliminary step, we obtained an overview of implemented or planned car-independent developments in Europe based on Internet databases, related reviews, and snowball sampling. We deemed a classification necessary to review the wide range of interventions found. The typology developed was aimed to structure the study and relate the reported evidence to the characteristics of the defined types. We drew on the car-free matrix proposed by Wright (2005) and added the function or rationale of the different implementations in their urban settings, which we considered an essential criterion. Other aspects that might be of interest in other research contexts were intentionally left out of this typology (for a more general taxonomy, see Melia et al., 2014). Based on these reflections, we identified four distinct types, each with different rationales, scales, and temporal scope. These include car-independent central areas (Type I), residential developments (Type II), citywide implementations (Type III), and temporary interventions (Type IV), as seen in Table 1.

### *2.2. Systematic Literature Review*

Thereafter, a systematic review of scholarly publications and, to a lesser extent, grey literature was conducted. Figure 1 describes the study selection process in detail. We limited our selection to publications and studies in English and German which examine policies for car-independent neighborhoods in Europe. On two databases, Scopus and Web of Science, we searched for articles with keywords to describe car independence,

**Table 1.** Typology of car-independent developments based on temporal scope, spatial scope, and rationale.

| Type | Temporal scope | Spatial scope | Rationale | Examples |
|---|---|---|---|---|
| I. Central areas | Long-term | Mid-scale | Air quality, attractiveness, economic competitiveness of city center, and reclaiming "streets for people" (climate goals) | Bologna, Groningen, Nuremberg, York, Brussels, Oslo |
| II. Residential developments | Long-term | Small- to mid-scale | Car-independent living, community, and construction cost savings | Vauban (Freiburg), Lincoln (Darmstadt), Floridsdorf (Vienna), Hammarby Sjöstad (Stockholm) |
| III. Citywide implementations | Long-term (short-term pilots) | Large-scale | Climate goals, air quality, citywide modal shift, livability, and reclaiming "streets for people" | Low traffic neighborhoods (London), Superblocks (Barcelona), Kiezblocks (Berlin) |
| IV. Temporary interventions | Short-term | Small- to mid-scale | Pilot, awareness, car-free experience, reclaiming "streets for people," sociability, and emergency response | Piazze Aperte (Milan), Leefstraat (Ghent), Summer Streets (Malmö, Gothenburg, Munich); car-free days (worldwide) |

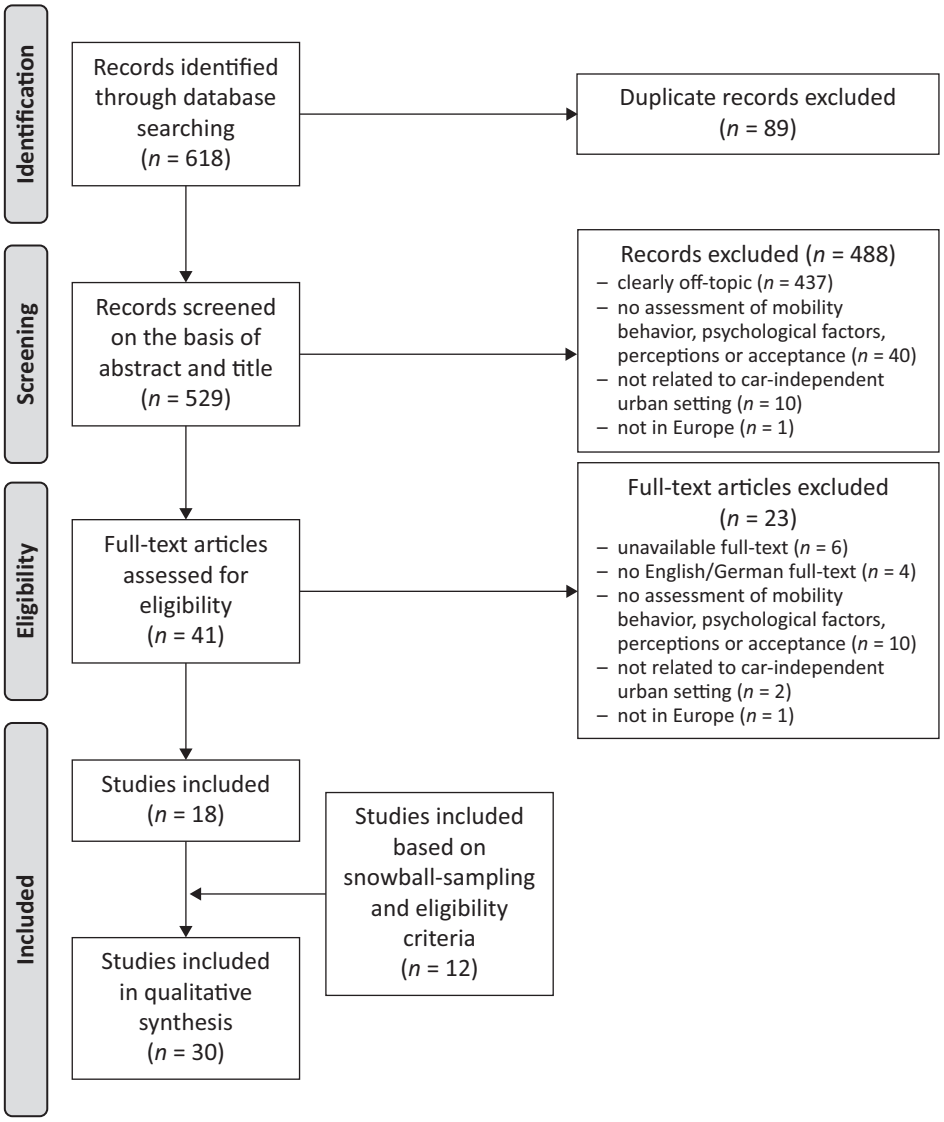


**Figure 1.** Flow chart of the study selection process.

such as "car-free," "car-reduce," "car ban," "*autofrei*," in combination with the spatial scope, such as "area," "neighborhood," "development," "city." In the Web of Science database, the search was additionally limited to the fields of transportation, environmental sciences, sustainability science, climate change, social psychology, and human geography. This resulted in 618 potential records. After removing duplicates (89), titles and abstracts were screened, resulting in the exclusion of 488 records which did not meet the inclusion criteria (see Figure 1). After the full-text screening, 18 studies were included that were related to car-independent urban settings and addressed residents' mobility behavior, psychological factors, perceptions, or acceptance of car-independent interventions. We found that some implementations were missing as not all use the identified keywords to describe car-independent interventions. Based on our expertise and through backward and forward snowballing, we complemented the search and included twelve additional sources. Nonetheless, we are aware that with this keyword search, we are examining only a small subset of mobility behavior research that addresses a particular type of intervention that is labeled car-free or similar. Supplementary sources were used to provide context but were not further defined as primary sources of the review.

## 3. Results

### *3.1. Summary and Quality of Studies*

Table 2 provides an overview of the included studies, their methodology where present, and whether they addressed mobility behaviors (mob.), psychological factors (psy.), perceptions (per.), and acceptance (acc.). It proved difficult to distinguish between the different concepts because of the variety of methodologies, ontologies, and wording in the studies. Table 3, moreover, displays the evaluation criteria that we considered for the corresponding categories, as mentioned in the included studies.

**Table 2.** Overview of the studies included.

| Reference | Case studies | Methods | Mob. | Psy. | Per. | Acc. |
|---|---|---|---|---|---|---|
| Type I. Central areas | | | | | | |
| Bromley et al. (2007) | Bristol, Swansea, Birmingham, Cardiff | Secondary research: Analysis of census data (from 1991 and 2001) and household surveys in two cases (primary data, $n = 541$) | x[d] | x[i] | | |
| Gundlach et al. (2018) | Berlin | Discrete choice experiment: Survey with students ($n = 334$), logit models | | | | x[t,q] |
| Hagen and Tennøy (2021) | Oslo | Longitudinal study: Surveys with users and employees in the city center ($n = 4{,}270$ to $n = 6{,}768$) | x[b] | | x[n,o] | |
| Nederveen et al. (1999) | Delft, Utrecht, Maastricht, Alkmaar, Groningen, Leeuwarden | Qualitative study: Informal interviews with residents (not stated) and interviews with representatives from resident groups ($n = 10$), document analysis | | | | x[q] |
| Rydningen et al. (2017) | Nuremberg, Freiburg, Strasbourg | Secondary research and expert interviews during site visits ($n = 6$) | x[f] | | | x[q] |
| te Boveldt et al. (2022a) | Brussels | Longitudinal quantitative study: Survey with residents ($n = 1{,}007$), employees ($n = 824$), and visitors ($n = 1{,}470$) | x[b,h] | | x[n] | x[s,q] |
| te Boveldt et al. (2022b) | Brussels | Longitudinal quantitative study: Survey with residents ($n = 1{,}007$), employees ($n = 824$), and visitors ($n = 1{,}470$), ordinal logistic regression analysis | x[h] | | | x[s,q] |
| Topp and Pharoah (1994) | Bologna, Lübeck, Aachen, York | Secondary research | x[a,e,h] | | | x[q] |
| Type II. Residential developments | | | | | | |
| Baehler and Rérat (2020) | Burgunder in Bern, FAB-A in Biel/Bienne, Giesserei in Winterthur, Oberfeld in Ostermundigen, Sihlbogen in Zurich, Klein Borstel and Saarlandstraße in Hamburg, Stellwerk60 in Cologne, Weißenburg in Münster | Cross-sectional mixed methods study: Household survey ($n = 571$) and interviews ($n = 50$) | x[c] | x[j,k] | | |
| Broaddus (2010) | Vauban and Rieselfeld, Freiburg | Secondary research, incl. official surveys and Nobis (2003) | x[c,d] | | | |

**Table 2.** (Cont.) Overview of the studies included.

| Reference | Case studies | Methods | Mob. | Psy. | Per. | Acc. |
|---|---|---|---|---|---|---|
| Type II. Residential developments (cont.) | | | | | | |
| Foletta and Henderson (2016) | GWL-Terrein in Amsterdam, Vauban in Freiburg, Hammarby Sjöstad in Stockholm, Västra Hamnen in Malmö, Greenwich Millenium Village in London | Secondary research | x[d] | | | |
| Kirschner and Lanzendorf (2020) | Bornheim, Frankfurt | Cross-sectional quantitative study: Survey with residents ($n$ = 1,027) | x[h] | | | x[q,u] |
| Melia (2014) and Melia et al. (2010) | Groningen, Vauban in Freiburg, GWL Terrein in Amsterdam, Saarlandstraße in Hamburg, Kornweg in Hamburg, Stellwerk 60 in Cologne | Secondary research, study visits, observations, and interviews | x[d] | | | x[r] |
| Morris et al. (2009) | European and UK residential developments | Secondary research | x[a,b] | | | x[r,q] |
| Nobis (2003) | Vauban, Freiburg | Cross-sectional study: Household survey ($n$ = 247) and individual questionnaire ($n$ = 438) | x[c,d] | | | x[r,v] |
| Ornetzeder et al. (2008) | Floridsdorf, Vienna | Cross-sectional mixed methods study: Survey in case study ($n$ = 42) and in reference settlement ($n$ = 46) and interviews ($n$ = 9) | x[d,e] | x[i,k] | x[p] | |
| Scheurer (2001) | Torup in Hundested, Bo90, Skotteparken and Hyldespjældet in Copenhagen, Floridsdorf in Vienna, GWL Terrein in Amsterdam, Slateford Green in Edinburgh, Stadthaus Schlump and Saarlandstraße in Hamburg | Cross-sectional quantitative study: Survey with residents in nine case studies ($n$ = 326) | x[c,d,e] | x[i] | | |
| Selzer and Lanzendorf (2022) | Lincoln and K6-Kranichstein, Darmstadt | Qualitative study: Interviews with residents ($n$ = 22), thematic qualitative text analysis in combination with a type-building text analysis | x[c] | x[j,k,l] | x[p] | |
| Selzer (2021) | Lincoln and K6-Kranichstein, Darmstadt | Qualitative study: Expert interviews ($n$ = 15) and interviews with residents ($n$ = 22), type-building text analysis | x[c] | x[l,m] | x[p] | x[r] |
| Sprei et al. (2020) | Settlements in Europe, focus on Sweden | Literature review, stakeholder interviews | x[c,b,d] | | | |
| Stubbs (2002) | Inner-urban London | Quantitative study: Survey ($n$ = 47) | | | | x[t,r] |

**Table 2.** (Cont.) Overview of the studies included.

| Reference | Case studies | Methods | Mob. | Psy. | Per. | Acc. |
|---|---|---|---|---|---|---|
| Type III. Citywide implementations | | | | | | |
| Aldred et al. (2019) | Enfield, Waltham Forest and Kingston, Outer London (Mini-Holland program) | Longitudinal quantitative study: Surveys with intervention and control sample ($n$ = 1,722), linear regression analyses | x[b,f] | | x[o] | x[u] |
| Aldred and Goodman (2020) | Enfield, Waltham Forest and Kingston, Outer London (Mini-Holland and Low Traffic Neighbourhood program) | Longitudinal quantitative study: Surveys with intervention and control sample ($n$ = 1,722), linear regression analyses | x[b,f] | | | |
| Scudellari et al. (2020) | Poblenou, Barcelona (Superblock program) | Qualitative study: Systematic document review, stakeholder interviews ($n$ = 8), field interviews with users ($n$ = 30) | | | | x[q] |
| Type IV. Temporary interventions | | | | | | |
| Bertolini (2020) | Street experiments worldwide | Systematic literature review | x[g] | | x[n] | |
| Burton (2003) | European "in town without my car" car-free day | Secondary data | x[g] | | | x[q] |
| Marcheschi et al. (2022) | Summer streets, Gothenburg and Malmö | Cross-sectional mixed methods study: Environmental audit ($n$ = 5), observations ($n$ = 73), and interviews ($n$ = 90); residents survey ($n$ = 1,049), hierarchical regression analysis | x[h] | | | x[q] |
| Nello-Deakin (2022) | Eleven pandemic-related street interventions in Eixample, Barcelona | Longitudinal quantitative study: GIS-based evaluation of traffic count data on intervention and control streets | x[a] | | | |
| Reutter (2003) | Johannesplatz, Halle (Saale) | Triangulated quantitative study: Observations, traffic counts, and household surveys | x[a,b] | | x[n] | x[r] |

**Table 3.** Evaluation criteria by category in included studies.

| Category | Evaluation criteria |
|---|---|
| Mobility behavior | [a] Traffic counts before and after, [b] change in mode use or ownership before and after, [c] self-reported change in mode use or ownership, [d] comparison of modal split or mode ownership with reference area, [e] comparison of kilometers (km) traveled by mode with reference area, [f] change in travel duration by mode, [g] shift in mode use or traffic volume (method unspecified), and [h] main mode or access to mode as an explanatory variable |
| Psychological factors | [i] Attitudes or motivations towards the residence, [j] attitudes towards modes, [k] pro-environmental or social values, [l] social norms or control, and [m] change of attitudes towards mode use |
| Perceptions | [n] Change in value or perceptions of public space or neighborhood, [o] change in perceived quality or accessibility of mode, and [p] perception of the physical or social environment |
| Acceptance | [q] Support towards implemented or future car-independent policies, [r] satisfaction with implemented or planned intervention, [s] change in support before and after, [t] preferences for different pull-and push-measures, [u] support for investment in active-mobility infrastructure, and [v] compliance with parking policies |

Of the 30 studies included, the majority consisted of Type II (residential developments) with 14 studies, followed by Type I (central areas) with eight, Type IV (temporary interventions) with five, and Type III (citywide implementations) with three. The oldest studies date back to the 1990s and early 2000s, although the renewed interest in this topic in the last five years (14 studies) highlights the timeliness of this topic. Nine studies relied on secondary data from official statistics and other studies, often supplemented by qualitative observations or informal interviews. Two studies were systematic literature reviews (Bertolini, 2020; Sprei et al., 2020), providing an overview of specific types of implementations (Type II and Type IV) and access to results that were not available in English or not captured by our search strategy. The other 19 studies used primary data, of which 11 analyzed quantitative data (e.g., surveys and traffic counts), four analyzed qualitative data (interviews and document analysis), and three used mixed methods (e.g., surveys and interviews). In older studies, the description of data collection and analysis methods or original sources was overall lacking, especially those using secondary data.

Evidence of more sustainable mobility behavior in car-independent areas was examined in 24 of the 30 studies. In four studies, traffic counts before and after the intervention were used as an indication of a mobility behavior change. This can be problematic as it could also be related to a citywide modal shift, a shift in routes, or a change in the number of visitors to the area. Only one study compared intervention streets with control streets (Nello-Deakin, 2022). The surveys' designs were mostly cross-sectional studies that captured changes in mobility behavior based on reported changes (e.g., Baehler & Rérat, 2020; Nobis, 2003) or compared modal splits and ownership in car-independent intervention areas with reference areas (e.g., Foletta & Henderson, 2016). The bias of retrospective self-reports of changes, the frequent lack of matching control groups, and the limited comparability of different data sources compromise the methodological soundness of most studies. Recent studies often used longitudinal study designs to address changes in mobility behavior, which have the advantage of providing more reliable results on causality rather than correlation. However, three studies were not representative, and two of the studies did not include a baseline survey before the intervention (te Boveldt et al., 2022a, 2022b). Only two of them used a robust longitudinal design with control groups and regression analysis testing for significance (Aldred et al., 2019; Aldred & Goodman, 2020).

Five studies examined changes in perceptions in some way, while eight used perceptions and psychological factors to explain reasons for moving to car-independent areas, variations in acceptance, or mobility behavior. Only Selzer (2021) addressed changes in attitudes in their qualitative study. Acceptance was addressed by 17 studies.

### *3.2. Car-Independent Central Areas*

From the late 60s on, pedestrian streets and car-free zones in city centers became a popular planning tool, especially in Europe (Orski, 1972). Since their role as employment and commercial centers typically predominates over their residential function, the primary intention of the early car bans or restrictions in central areas was to increase their attractiveness and boost the local economy (Orski, 1972). With growing awareness of the car's negative health effects on humans, lowering local air pollution and accidents has been a priority (Orski, 1972; Rydningen et al., 2017). Recently, there has been a renewed interest in enlarged car-free city

centers. Cities like Brussels, Oslo, and Madrid announced or have already implemented their plans to further reduce car traffic in their centers (te Boveldt et al., 2022b). Narratives of these implementations shifted to GHG reductions and tackling car dominance towards "streets for people" (Hagen & Tennøy, 2021; te Boveldt et al., 2022b).

Overall, reviewed literature shows high acceptance rates among residents and users for both older and newer implementations (Gundlach et al., 2018; te Boveldt et al., 2022b; Topp & Pharoah, 1994). This combination, along with pull measures, was found to benefit acceptance rates for car restrictions (Gundlach et al., 2018). The evaluation of Brussels' recent extension of its central car-free area demonstrated that support had grown since its introduction (te Boveldt et al., 2022b). They found that among car drivers, there was a greater degree of disapproval, while cyclists and pedestrians, young individuals, and residents residing in close proximity exhibited greater levels of support (te Boveldt et al., 2022b). Contrary to the high approval of citizens, car bans in inner-city commercial areas typically face initial resistance from retailers who fear lost sales (Rydningen et al., 2017; Topp & Pharoah, 1994). In the case of Oslo, this resulted in a modified implementation approach (Cathcart-Keays, 2017). Spill-over effects in adjacent neighborhoods, i.e., higher parking pressure and increased traffic volumes, can result in dissatisfaction among affected residents and negative perceptions of the car-restricting policies (Nederveen et al., 1999).

While Topp and Pharoah (1994) identified a decrease in car use for trips to centers and an increase in the use of pedestrians, bicyclists, and public transportation, the results in Brussels were not as conclusive. There was a shift to sustainable modes for trips to the pedestrian zone by visitors and residents, however car use increased among people working in the center (te Boveldt et al., 2022a). Perceived safety was found to be low and decreased after the introduction (te Boveldt et al., 2022a), which potentially impacts walkability. The authors concluded that the causal relationship between the car-free intervention and mode shift remained unclear (te Boveldt et al., 2022b). This is consistent with the survey results from Hagen and Tennøy (2021) who found no clear change in mode choice among commuters and users of Oslo's city center before and after the introduction of street allocation measures. Still, with the improvement of cycling and walking conditions, perceived comfort and accessibility by those modes increased. It was found that while on-street parking was massively reduced, the percentage of businesses offering off-street parking to their employees increased. This provided a possible explanation for the slight increase in car driving (Hagen & Tennøy, 2021). Several authors suggested that due to its limited scope, there is little to no effect on the overall behavior or traffic volume (Orski, 1972; Topp & Pharoah, 1994). In the case of Oslo, the restrictions on motorized traffic on central streets were preceded by infrastructural changes and the tunneling of the city center and therefore had little impact on overall traffic volumes (Hagen & Tennøy, 2021). Moreover, trips to and within the center were already predominately done by sustainable modes of transport, leaving little potential for further reductions in car use (Hagen & Tennøy, 2021; Rydningen et al., 2017).

In the long-term, car-reduced city centers appear to attract new residents with low car ownership who value walkable distances to work and amenities (Bromley et al., 2007). However, this can lead to gentrification, as in the case of the British cities studied by Bromley et al. (2007), where highly educated young men with higher incomes were the main beneficiaries.

### *3.3. Car-Independent Residential Developments*

The idea of residential developments with limited access and parking for cars to promote car-independent lifestyles and provide a healthy environment emerged in Europe during the 1990s (Baehler & Rérat, 2020; Scheurer, 2001). They range from "visually car-free" with no on-street parking but an abundant supply of off-street parking, "car-reduced" with lower parking provisions than standard, or (almost) completely "car-free" with the most stringent restrictions on car access and ownership (Morris et al., 2009). From the perspective of land developers, innovative mobility concepts are often introduced to reduce minimum parking requirements and thus construction costs (Seemann & Knöchel, 2018). Unlike pedestrianized city centers which are typically retrofitted, all permanent car-independent settlements found in this research were greenfield or brownfield developments where new residents had moved in after completion.

Car ownership and use were predominantly compared to the corresponding figures for the whole city and to other comparable contexts which proved to be lower in the majority of cases (Broaddus, 2010; Foletta & Henderson, 2016; Nobis, 2003; Sprei et al., 2020). Respectively, the share of sustainable modes was found to be substantially higher, also among car-owning households in the car-independent settlements (Nobis, 2003). Comparison to similar settings with conventional car policies pointed to the importance of financial, contractual, and spatial disincentives for parking to effectively reduce car dependency (Broaddus, 2010; Ornetzeder et al., 2008). The evaluation of nine case study developments by Scheurer (2001) showed a high ambiguity in terms of car use and ownership. Car ownership ranged from 8% in Floridsdorf, Vienna, where car ownership is prohibited by contract, to approximately 75% in Stadthaus Schlump, Hamburg, exceeding the city average. Notably, most of the developments studied by Scheurer (2001) were quite small and confined to only one block or house, indicating that the capacity to reduce car dependency without strict constraints on ownership is limited. The importance of scale was also discussed by Morris et al. (2009),

who suggested that larger neighborhood-level mobility policies are needed rather than small-scale car-free housing which cannot provide benefits such as nearby amenities or low-emission and safe environments. In two studies, residents were asked to report any change in mobility behavior and car ownership since moving. They found a considerable effect of the new residents on reducing car ownership and the tendency to use sustainable modes more often (Baehler & Rérat, 2020; Nobis, 2003). Several studies showed that the mobility behavior of people is already more likely to be oriented toward sustainable modes of transport and many had already lived car-free before moving (Baehler & Rérat, 2020; Nobis, 2003; Selzer, 2021; Selzer & Lanzendorf, 2022). The reinforcing effect on existing sustainable mobility patterns is thus more pronounced than an actual shift from car-dependent to car-independent mobility choices (Selzer, 2021), whereby the relocation itself often provides the final impetus to abandon the private car.

Higher environmental awareness and negative attitudes towards cars, as well as the social context, were found to be connected with lower car use and ownership (Baehler & Rérat, 2020; Ornetzeder et al., 2008; Scheurer, 2001). Because people self-selected themselves towards car-reduced settlements, acceptance and satisfaction were typically high for this type (Nobis, 2003). Yet, several studies found that car owners frequently disregarded or circumvented parking rules (Nobis, 2003; Scheurer, 2001; Selzer, 2021). Acceptance and (partial) demotorization eventually grow with increased duration of residency in car-reduced neighborhoods according to Selzer (2021). Although there is a lack of documented and evaluated retrofitted car-independent residential areas, two of the found studies explored the potential of car-restricting policies in existing neighborhoods. In a central urban neighborhood of Frankfurt, study participants declared an overall high acceptance for all types of on-street parking policies (Kirschner & Lanzendorf, 2020). Interestingly, Kirschner and Lanzendorf (2020) found that car-owning residents with the intention to reduce their car use rated car-restricting policies similar to already car-free households in contrast to frequent car drivers. This speaks to the importance of psychological factors that anticipate actual change. In an earlier study, Stubbs (2002) found that homeowners in urban London were still opposed to the idea of car-free living.

The systemic context in which these developments exist seems to be the most limiting factor for car-independent lifestyles. In rural settings, constraints in accessibility and limited mobility options can lead to long-distance trips by motorized transport and even growth in car ownership despite pro-ecological attitudes and sustainability efforts within the settlement (Scheurer, 2001). Selzer and Lanzendorf (2022) found that people often still own or use a car to reach car-dependent areas in the outskirts for leisure and commuting trips. It was also the most often mentioned restraint for car-free households in Vauban (Nobis, 2003). This demonstrates the interlock of the car with lifestyle decisions and traditional urban planning, often separating functions of working, living, and recreation. The association of the car with more freedom, greater flexibility, and faster trips, as well as positive experiences and emotions developed over the years, still persist among many residents in car-reduced neighborhoods and hinder a modal shift (Selzer & Lanzendorf, 2022).

### *3.4. Car-Independent Citywide Implementations*

Citywide policies aim to change the city's mobility system as a whole. Typically, rationales behind citywide car-independent strategies focus on climate change mitigation, modal shift, and livability goals including freeing space from the car for other uses and greenery. Although rare, some cities are in the process of implementing citywide strategies to significantly reduce their car traffic. A well-known example is Barcelona's superblocks or *superilles* which inspired similar movements in other European cities such as the *supermanzanas* in Vitoria-Gasteiz, *Superbüttel* in Hamburg, *Kiezblocks* in Berlin, or *Supergrätzl* in Vienna. They propose an organization of the city into neighborhood units, removing traffic and parking from the inner streets of communities and prioritizing active mobility and stationary uses (Scudellari et al., 2020).

To date, only three superblocks have been realized as part of Barcelona's comprehensive plan to redesign the city. In 2020, the city of Barcelona deviated from its original plan, introducing the concept of "green corridors" as a means to address public resistance (Nello-Deakin, 2022). Similarly, acceptance of the first pilot superblock in Poblenou was divided, with protests often coming from residents who did not have the benefits of living in the interior (Scudellari et al., 2020). In particular, the non-existent bike lanes and the traffic routing on the outer roads, which were foreseen to be adapted in the theoretical concept, led to dissatisfaction among users, but also the use of short-term means was less accepted than constructive improvements (Scudellari et al., 2020). Overall, it also revealed a problem of inequity between those who will benefit and those who will not.

London's scheme of Low Traffic Neighbourhoods and Mini-Holland program can also be considered a citywide strategy fostering car independency by introducing modal filters to inhibit through traffic in its neighborhoods and improving active mobility infrastructure. Its first implementations in Enfield, Waltham Forest and Kingston in Outer London have been thoroughly investigated (e.g., Aldred et al., 2019; Aldred & Goodman, 2020). By comparing intervention groups with control groups, Aldred et al. (2019) displayed that, especially in areas most affected by the interventions, active mobility trips and duration significantly increased as well as the perception of local cycling infrastructure improved. The impact on car use and ownership in low traffic neighborhoods was positively trending with statistical

significance only in later waves (Aldred & Goodman, 2020). Although acceptance was not directly measured, the percentage of people who believed that too little was invested in cycling increased after introducing the measures (Aldred et al., 2019). Simultaneously, more people felt that too much money was spent, indicating a growing divide between those who were satisfied and dissatisfied with the interventions.

### *3.5. Car-Independent Temporary Interventions*

Temporary interventions, also known as tactical urbanism or street experiments, are short-term measures ranging from the repurposing of parking spaces to the redesign of whole streets (Bertolini, 2020). They can be either recurring events, such as car-free days, play and summer streets, or one-time interventions over a period of several weeks, months, or even years, such as the Piazze Aperte program in Milan. Typically, they act as demonstration projects to raise awareness and allow citizens to experience a car-free environment (Nieuwenhuijsen et al., 2019) or as a pilot to learn in an iterative approach for later permanent implementation or upscaling (Lydon & Garcia, 2015). In research, they have been understood as niche experiments, acting in the car system or regime aiming for systemic change through incremental changes away from "streets for traffic" towards "streets for people" (Bertolini, 2020, p. 2).

According to Burton (2003), car-free days in Spain gained widespread acceptance, reduced automobile use, and increased the use of public transportation during the event. Yet, the interventions were claimed to have no lasting effect on traffic levels (Burton, 2003). Similarly, Bertolini (2020) found strong evidence in their review of street experiments for positive social impacts and increased physical activity, especially for play streets and open streets or *cyclovía* events, but no exploration of the experiments' ability to induce transformational change. Notably, Nello-Deakin (2022) demonstrated the effect of traffic evaporation in pandemic-related interventions in Barcelona, suggesting the potential for prolonged experimentation to induce modal shift or other adjustments in the form of destination shift. However, the three-year trial of a car-reduced neighborhood in Halle showed only a shift in traffic from car-restricted streets to main roads (Reutter, 2003). Car ownership even increased, which was attributed to a shift in the demographic of residents towards households with higher incomes.

As a result of a heated participation process, the Halle project had to adjust from a more radical car-free solution to a car-reduced solution (Reutter, 2003). After adjusting, the overall acceptance of the measures increased and perceptions of the quality of the neighborhood improved. It is noteworthy that the measures were not made permanent after the trial. Marcheschi et al. (2022) found that the acceptance of summer streets in Stockholm and Malmö was influenced by the attitudes and perceptions of users. Not surprisingly, individuals who identified as drivers and owned a car had lower acceptance rates. Individuals with longer residency and positive perceptions of quality of place also had lower levels of support for the measures, perceiving them as a disturbance. The authors recommended focusing on creating sociable places to increase acceptance.

## 4. Discussion

This review divided existing measures in Europe into car-independent central areas, residential areas, citywide measures, and temporary measures. This distinction by reason and scale synthesized the current state of research on car-independent developments regarding mobility behavior (change), psychological factors, perceptions, and acceptance. As such, a broader overview of car-independent neighborhood strategies was obtained than was previously done by Sprei et al. (2020) and Melia et al. (2010), who limited their review to new-built residential developments.

Earlier initiatives to car-free central areas (Type I) focused on the economic success of city centers and local emission reductions, while current projects also target climate goals, i.e., modal shift, and tackling car dominance in public spaces. The impact on people's mobility behavior, however, is generally limited to a few trip purposes and remains ambiguous. Evaluation of acceptance rates commonly displayed high overall support among users but strong (initial) opposition of businesses. Matching their primary motive of enabling car independent living, more sustainable mobility patterns were observed among residents of settlements of Type II compared to control areas or their city context. However, it is often unclear whether this is a causal relationship with the settlement design or—in the absence of a comprehensive (longitudinal) evaluation—a consequence of self-selection. The raised assumption of self-selection is consistent with studies showing that people with positive experiences and attitudes towards certain modes of transportation are more likely to live in areas that support their transportation preferences (e.g., Cao et al., 2009; De Vos et al., 2018). To achieve citywide car-independent environments, it is important to implement and evaluate practices beyond new developments and city centers. Rather little is known about transforming existing residential neighborhoods into car-independent areas (Types III and IV). This can be primarily attributed to the fact that there has been limited experience with citywide implementations (Type III) and little evaluation of temporary interventions (Type IV). The two examples found of citywide strategies, Low Traffic Neighbourhoods in London and superblocks in Barcelona, have only been partially implemented and evaluated in their pilots. Therefore, the question remains open regarding how existing structures can be changed on a large-scale that challenges the political, cultural, social, and functional lock-ins of the automobile regime, and what impact this would have on a city scale. Not surprisingly, there

appears to be a greater polarization in terms of perceptions and acceptance among people in Types III (citywide implementations) and IV (temporary interventions) than in Types I (central areas) and II (residential developments). Experimentation has often been the starting point to incrementally initiate citywide implementation, Type III and IV are, therefore, strongly interrelated.

The results showed that (regardless of the type of car-free development) travel behavior, psychological factors, perceptions, and acceptance are interrelated (Marcheschi et al., 2022; Selzer & Lanzendorf, 2022; te Boveldt et al., 2022b). In the context of other research, it has been identified that attitudes have a strong influence on mobility behavior and that changing attitudes through improvements to the urban environment can contribute significantly to sustainable mobility behavior (De Vos et al., 2018). Yet, this has not been reflected in the focus of the found studies. Although not the focus of this research, several studies suggested that people value car-independent environments for their sociability (Bertolini, 2020; Ornetzeder et al., 2008; Scheurer, 2001). Conversely, they may perceive them as a threat to their usual environment (Marcheschi et al., 2022) or as reinforcing social inequalities (Nederveen et al., 1999; Scudellari et al., 2020). Practitioners and researchers are therefore advised to pay particular attention to the social impacts (and perceptions thereof) of car-independent neighborhood interventions which may foster or impede acceptance and positive experiences of car-independent mobility.

## 5. Conclusions

This article aimed to provide a typology of car-independent developments and a comprehensive literature review of their implications, enabling people to live without being reliant on private motorized transport ownership and use. To link characteristics, behavioral, and psychological implications, the car-independent developments were grouped into four types: car-independent central areas, residential developments, citywide implementations, and temporary interventions. Most studies focus on residential developments, more specifically, newly built housing developments.

While some knowledge is available regarding the potential environmental, social, and health benefits of car-independent cities, as well as barriers and drivers of the transition, few research papers discuss the actual behavioral and psychological implications. When impacts are assessed, a focus is often on mobility behavior, which changes depending on the measures implemented. In general, changing the environment in existing neighborhoods is much more challenging. The review shows a lack of knowledge on attitudes, perceptions, and acceptance among people affected by car-independent developments. It could be argued that actual impact is achieved through behavioral change only. However, the psychological factors should not be underestimated, as they provide the basis for a change in travel behavior. In terms of evaluation, the methods employed in many studies do not enable a complete and comprehensive understanding of causes and effects. Overall, there is a lack of reliable evaluations, but this has improved in more recent studies. While earlier studies primarily focused on mobility behavior, often using traffic counts as a proxy, perception has increasingly been included as one of the variables to be examined, while psychological factors such as attitudes remain scarcely studied in car-independent neighborhood interventions.

Future studies should focus on (a) other types of car-independent developments beyond newly built housing; (b) dedicated assessments of changes in psychological factors, perceptions, and acceptance; and (c) increased long-term observation of changes in behavior and mindset. Additional insights and knowledge on the impacts of car-independent developments, including the underlying causes, will help to derive recommendations for practical implementations and support the transformation of cities towards car independency.

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## Conflict of Interests

The authors declare no conflict of interests.

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