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Geographies of new mobility services: The emergence of a premium mobility network space

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ABSTRACT

This paper offers a critical perspective on spatial supply structures of new mobility services using the example of carsharing, bikesharing and e-scootersharing. Following conceptual consideration of Splintering Urbanism, the emergence of a Premium Mobility Network Space (PMNS) is propounded; i.e. an exclusive supply of interconnected mobility services that is inscribed in the social and action spaces of the economically and culturally privileged elites of Western (post-industrial) societies by the marked-based mobility providers. Regarding this, we assume that the PMNS is effective intra- and interregionally at different spatial scales because the social and action spaces of the post-industrial elites are correspondingly organized intra- and inter-regionally. A (preliminary) comparative study of German cities over 300,000 inhabitants in this paper suggests that this PMNS mainly extends across the economic and cultural prosperous context of Global Cities. In this city network, the same few market players of Carsharing, Bikesharing, E-Scootersharing, etc. can be located over and over again; i.e. travelers between the cities experience a reduced transaction effort because they do not have to install new apps to use the certain services and find the same services in every global city. By contrast, the supply of new mobility services in other cities that are not part of the global city network – and this applies in particular to the economically weak old industrial cities affected by structural change – is poor to non-existent. In a second step, bivariate and multivariate analyses using Frankfurt/Main as a case study reveal that the socio-spatially exclusive supply of new mobility services continues in the economically and culturally prosperous areas within the global cities themselves. Methodically, the city comparison is based on an Internet and media analysis in order to identify the supply of new mobility services by cities. For the analyses in Frankfurt, certain supply structures were overlaid with official city district data. Overall, our findings point to a spatially selective supply pattern of new mobility services within economically and culturally prosperous spaces, suggesting an interconnected mobility network in the sense of a PMNS. By contrast, urban peripheries beyond the global city are bypassed, i.e., on the one hand, the social spaces of the marginalized underclass in the socio-spatial peripheries and, on the other hand, the dispersed suburban housing estates associated with a traditional middle class that remain oriented toward private automobility. In conclusion, these observations are of great importance because they contradict any sustainability ascriptions that are discursively produced around the supply of new mobility services. The suspicion arises that developing new mobility services under market-based developments only permits socio-spatially fragmented supply structures, but not the expected spatially ubiquitous solution that is needed for sustainable everyday mobilities.

1. Introduction

In the field of new mobility services (carsharing, bikesharing, e-scootersharing, ridesharing etc.), this paper starts with the notion of a dialectical relationship between the societal construction of a new sustainable transport system and social fragmentation processes resulting from market developments. This critical approach is important because new mobility services are increasingly discussed as an important part of the everyday mobilities of the global north's post-industrial societies. In particular, the dynamics in new mobility services stimulate

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imaginaries of a "post-private car era" (Firnkorn and Müller, 2015), suggesting a possible transition from the hegemonic transport regime of private automobility towards multimodality, i.e. the flexible, situation-specific use of different transport modes in the shape of interconnected mobility services (e.g. of trains, buses, carsharing, bikesharing, e-scootersharing etc.) (e.g. Geels, 2012). Since everyday mobilities represent a spatial practice, geographic analytics are applied in the following to reveal the mismatch between ubiquitous sustainability aspirations and socio-spatially selective supply structures in the field of new mobility services.

Following Böhler (2010), mobility services can be defined as the supply of a service that is related to everyday mobility demand. In this definition, mobility services are, of course, not new, because public collective transport (buses, trains, trams, etc.) have been long established, are ubiquitous, and are usually supplied by the state in many countries of the global north. New mobility services, however, are seen to be newer services, in which for instance originally private individual transport (car, bicycle, etc.) is now also conceptually detached from purely private use and embedded in the post-industrial context of tertiary, service-based economies. In this respect, new mobility services are far less subject to the principle of public welfare than traditional public collective transport, but rather underlie the capitalist principle of marketability, i.e. the business premise of adapting services to changing market conditions in advance and generating profits within this framework. Such new mobility services can be prominently identified in the form of business-to-consumer services (B2C), whereby consumers rent a certain transport mode directly from the provider in return for payment of a fee, but no longer need to own the mode (e.g., Rifkin, 2000). Well-known examples include station-based and flexible carsharing (see e.g. Kent and Dowling, 2013; Münzel et al., 2018), bikesharing (see e.g. Parkes et al., 2013; Shaheen et al., 2013) or also e-scootersharing (see e.g. Fitt and Curl, 2020; Moran, 2021).

The above-mentioned sustainability attribution of mobility services is performed in the course of their conceptual embedding in a multimodal transport regime, which is advanced in applied reflexivity by transport policies (e.g. BBSR and BMI, 2021; European Commission, 2018). In this context, the widespread implementation of modern information and communication technologies (ICT) since the 2010s in particular stimulates imaginaries of a multimodal transport regime in the guise of smart mobility (Groth and Kuhnimhof, 2021). This implies a highly situation-specific and flexible mode choice between a wide variety of interconnected mobility services becoming a common practice for the first time, and thus constitutes an adequate substitute to the private automobile (Canzler and Knie, 2016; Docherty et al., 2018; Marsden and Reardon, 2018). The transport-policy-motivated promotion of new mobility services takes this development into consideration and can be outlined in two respects as a reflexive process of criticism of the status quo and a search for sustainable alternatives as follows. First, criticising the hegemonic transport system of private automobility as "unsustainable" in terms of its underlying fossil fuel metabolism, i.e. for instance, in terms of its dependence on non-renewable fossil fuels with respect to fossil inputs and its contribution to climate-damaging emissions with respect to fossil outputs (Fischer-Kowalski and Hüttler, 1998). Second, when seeking environmentally sustainable alternatives, new mobility services gain a good reputation because they are directly related to highly multimodal transport use (e.g. Kopp et al., 2015; Murphy and Usher, 2014), with the car being used significantly less often and for shorter distances in multimodal travel patterns (Nobis, 2007).

However, first studies criticise the market-based development of new mobility services, suggesting a spatially selective supply of service providers. Although these providers promote their services under the label of sustainability, they remain bound to the principles of profit maximisation in the placement of their products and services and direct them solely to socio-spatially identifiable target groups. This means, for example, that business areas are defined in which the mobility services can be rented and must be returned. Thus, it must be assumed for the field of new mobility services that the difference between the social claim of creating a ubiquitous ecologically sustainable alternative to private automobility on the one hand and the spatially fragmented supply on the other counteracts the transformation process from automobility to multimodality. In this respect, discussions refer to a multimodal divide, i.e. a division of societies according to spatial opportunities to participate in ecologically sustainable, multimodal transport systems based on new (or interconnected) mobility services (Bauriedl and Wiechers, 2021; Groth, 2019). From a geographical perspective, this results in a socio-spatially fragmented service, which can be problematised as "Splintering Urbanism" (Graham and Marvin, 2001) or "Platform Urbanism" (Leszczynski, 2020; Srnicek, 2017; Stehlin et al., 2020).

Against the backdrop of the dialectical relationship between discursive ascriptions of sustainability and the market embedding of new mobility services, we empirically follow up on criticisms related to the spatially fragmented supply structures of new mobility services. Theoretical considerations on splintering urbanism and related theories are intended to guide our approach. The underlying questions are: *i. To what extent must the supply structures of new mobility services be understood as (socio-)spatially selective in a post-industrial (service-based) contextualisation? ii. Which socio-spatial patterns with which particular (socio-economic and socio-cultural) characteristics are related to the offer of new mobility services?*

To answer the research questions, the study is structured as follows. Section 2 outlines our theoretical perspectives for interpreting the geographically uneven development of new mobility services. Section 3 outlines the methods for a city comparison regarding the supply of new mobility services as well as the suitability of Frankfurt/Main as a case study for our research question and the data set. Section 4 presents the findings of the city comparison as well as bivariate and multivariate models regarding supply structures and correlating socio-spatial characteristics in the case of Frankfurt/Main. At this point, it is worth noting in advance that we have chosen an explicitly quantitative analytical approach and thus differ from the many qualitative studies in the field of splintering urbanism. In this respect, we see the quality in the quantitative analytical approaches in making specific structural patterns of the unequal supply of new mobility services countable. Finally, we discuss our findings in the light of theoretical considerations and our research question and draw a conclusion with regard to the discursive ascriptions of new mobility services as a sustainable alternative to private automobility (Sections 5).

2. Theories

2.1. Splintering urbanism and the premium mobility network space

In our theoretical consideration of the uneven spatial distribution of the supply structures of new mobility services, we draw on thinking from the research context of splintering urbanism (for an overview, see also Coutard, 2008; Wiig et al., 2022). Graham and Marvin (2001) prominently introduced the thesis of splintering urbanism after the turn of the millennium to address the socio-spatially fragmented development of infrastructure networks and services in Western post-industrial countries (e.g. transportation, telecommunications, energy, water supply networks). They attribute this process to the increasingly (neoliberal) market-oriented planning, organisation and operations that underlie modern infrastructures and services in today's post-industrial societies. In this respect, today's policymakers and planners are much more selective than they were in post-war modernity under conditions of social cohesion and corresponding regulatory practices (Coutard and Rutherford, 2017). Therefore, splintering urbanism can be read as a critique of the dissolution of the once-common practice of ubiquitous supply and integrative functions of modern infrastructures. Graham and Marvin (2001) state that in post-industrial societies it is primarily areas

with purchasing power and consumers that benefit from the expansion of infrastructures and services. By contrast, marginalised areas with far less purchasing power are only provided – if at all – with the most basic, legally prescribed minimum services. This creates Premium Network Spaces of economically and culturally privileged groups on the one hand, and "network ghettos" on the other; i.e. marginalised areas bypassed by market-driven infrastructure planners. A number of researchers have empirically demonstrated such spatially fragmented development by using specific infrastructures as examples, such as in the fields of water or transport (e.g. Botton and de Gouvello, 2008; Kooy and Bakker, 2008; Oviedo Hernandez and Dávila, 2016).

In a decent conceptual following of Graham and Marvin (2001), we hypothesise that where the rise of new mobility service structures becomes socio-spatially relevant is in the development process of a *Premium Mobility Network Space* (PMNS). By PMNS we refer to a socio-spatially exclusive space of diverse and barrier-free interconnected (multimodal) infrastructures and supply structures of publicly and/or privately organised transport and mobility services beyond the traditional exclusivity of private automobility. Taking Graham and Marvin's (2001) considerations into account, we assume a certain socio-spatially selective inscription of the new mobility services into the social and action spaces of the post-industrial economic and cultural elites. It can be assumed that these elites represent the target groups of the usually market-oriented mobility service providers, since the symbolic aspects associated with certain mobility services (flexibility, sustainability, etc.) correspond with the overarching value orientations of the post-industrial elites (e.g. desire for flexibility, participation in sustainable mobilities, etc.).

By associating the PMNS with the notion of elites as being the target groups of mobility service providers, we do not mean the very small upper class of the super-rich (CEOs of top companies, media and sports stars, oligarchs, monarchs, etc.). While this would certainly be legitimate in terms of their economic and cultural influence, this upper class has no need for a PMNS. This social class has its private multimodal luxury fleets (private jets and helicopters, yachts, chauffeurs for luxury limousines, etc.) (e.g. Beaverstock and Faulconbridge, 2013).

Rather, we understand here the large new middle class as an elite that has constituted itself in the course of class formation processes in post-industrialism (Reckwitz, 2020, 2021). It is a bourgeois elite of high-skilled people, composed of different social milieus and predominantly employed in the post-industrial knowledge and financial economies of the global north (and here especially the global cities). Reckwitz (2021) conceives the concept of class here in the tradition of Bourdieu (2010 [1984]) as an economic, cultural and political entity: They distinctively (re)produce the same (or similar) social and action-spatial structures and defend them as their lifestyles, along with the corresponding maxims of life, notions of everyday life and certain practices (ibid.). Following Reckwitz (2020), the new middle class is gaining elite status by stylising its (urban/cosmopolitan/flexible) lifestyles (and the value orientations associated with them) discursively into overarching maxims and seeking to impose them as new norms and legitimate tastes (ibid). Associated with this are, for example, a hypermobile cosmopolitanism instead of a regionalised communitarianism, flexibility and delimitation instead of traditionalism and nationalism, sustainability instead of the exploitation of fossil resources, etc. (e.g. Reckwitz, 2020, 2021; Strenger, 2019). These distinctive value orientations are also related to certain class-specific (green) practices in everyday mobilities (Groth et al., 2021). And that might make the new middle class an interesting target group for the new mobility service providers.

The designation of a PMNS as a socio-spatially exclusive mobility space, equipped with modern mobility apparatuses for the new elitist middle class (conceptualised as post-industrial elite), has relevance for two research directions: First, in the context of Graham and Marvin's (2022) call to search for newer and novel fields of action of splintering urbanism itself, by placing the socio-spatially fragmented developments of new apparatuses in the context of market-based services that are supposed to be related to 'applied reflexivity' (Beck 1992 [1986]; Beck et al. 2007 [1994]; Giddens, 1992); i.e. those modernist advances that claim to produce effective counter-hegemonies to ecological ruin (e.g. Canzler and Knie, 2016; Geels, 2012; Kent and Dowling, 2013). In reality, however, the socio-spatially selective supply configuration through market-based developments runs the risk of promoting reflexive modernisation merely as a distinctive attribute of the new middle class. In this way, the social divide along class boundaries on ecological issues could be exacerbated, e.g. by the new middle demanding for collective behavioural shifts away from non-sustainable private automobility, but which is not even possible elsewhere. Second, as a corrective within (geographic) transport and mobility research, which adopts from a largely (traditional) "3D" (Cervero and Kockelman 1997) or "demographic perspective" (Löw, 2011) as an explanation for the uneven distribution of supply structures of new mobility services; and, in doing so, risks reducing consideration of dynamic developments in mobility services to large, densely populated cities (e.g. Docherty et al., 2018; Parkes et al., 2013; Shaheen et al., 2015). This shift in perspective in transport and mobility research is not trivial because – in line with critical infrastructure studies – it highlights the danger that crucial development processes in mobility services will continue to be restricted to the social and action spaces of post-industrial elites as economically solvent and culturally aware customers. The possible connection between the fragmented supply structures of new mobility services and the social and action spaces of post-industrial elites can be discussed inter-regionally and intra-regionally on different spatial scales, taking into account further theoretical considerations on socio-spatial polarisation and class formations in post-industrialism.

2.2. Spatial scales and frontiers of the premium mobility network space

At the inter-regional scale, the PMNS based on interconnected mobility services spreads across the economically prosperous network of global cities where the aforementioned post-industrial elites predominantly live and work. Following the discussion on "World Cities" (Friedmann, 1986; Friedmann and Wolff, 1982), Sassen (1991) introduced the concept of global cities at the end of the 20th century, describing the powerful formation of global cities that had resulted from the financial, service and control interdependencies of international capital in the transition to post-industrialism since the 1970's. In this respect, global cities have a largely homogeneous economic and cultural profile, according to which they resemble each other more than other regions and cities within their own countries (Löw, 2001). The emergence of this cultural and economic similarity of cities takes place in a process of exchange, which for example has also been described by Castells (2001) as a "Space of Flows"; i.e. involving the steady flow and exchange of information, goods and indeed people, in particular the economic and cultural elites, between these cities by means of ICTs and international transport hubs (Kesselring, 2009). Consequently, specific apparatuses are materialised in global cities which address economic and cultural elites (e.g. excellence-oriented educational institutions, high-priced gastronomy and other services such as large museums, theatres, auditoriums, etc.). In terms of people's mobilities, the Space of Flows is precisely based on the PMNS. The PMNS is (re)produced, on the one hand, by the massive supply and demand of exclusive high-speed transportation (airplanes, high-speed trains, etc.), which presuppose global mobilities between the prosperous (global) cities. On the other hand, it is (re)produced by the local development and use of high-quality mobility services for local and regional mobilities.

However, accentuating the performance of global cities with regard to the dynamic developments of new mobility services in a comparison between cities runs the risk of neglecting the reproduction of socio-spatial fragmentation within the (global) cities It can be assumed that the PMNS is also geared intra-regionally–i.e. within the global cities–exclusively to the post-industrial elites as economically solvent and culturally aware customers; i.e. the socio-spatially fragmented supply of

interconnected mobility services in the context of splintering urbanism is further continued at this spatial scale.

This assumption requires a more detailed understanding of the social structure of post-industrial Western societies with their specific class formations, which goes further than the above-mentioned understanding of new post-industrial middle class. Here, a first link can be drawn to theoretical considerations on social polarisation tendencies within global cities as a result of a polarised labour market (e.g. Hamnett, 2001; O'Loughlin and Friedrichs, 1996; Reckwitz, 2021). On the one hand, there are (post-industrial) employment structures for the high-skilled new middle class mentioned above that sustain the globalised knowledge and financial economies. On the other hand, there are simple unpretentious services for a new (no-longer unionised) precarised service or underclass of the low-wage sector and the emerging gig economy in post-industrialism (e.g. platforms designed for the short-term procurement of household assistance, cleaning and handyman services, furniture assembly or also mobility services) (e.g. Crouch, 2019; Eribon, 2013; Esping-Andersen, 1993; Nachtwey, 2018; Putnam, 2016). They represent the heirs of the once proud working class who have suffered a social (and in particular economic) decline under the structural change from industrial modernity to post-industrialism (and the associated neoliberal reforms around deregulation and flexibilization of labour markets and the dismantling of the welfare state) (ibid.). Finally, as a third social class, there is an old (traditionally oriented) middle class rooted in traditional professions (crafts, middle service, administration, etc.) (Reckwitz, 2021). It is the cultural heir of Fordist societies, where it was the bearer of social hegemony with regard to certain traditional values (communitarianism, traditional gender roles, striving for material wealth, family cohesion, work ethos, emotional car orientation, living out of fossil-based lifestyles, etc.) (ibid.). Reckwitz argues that this social class is suffering a cultural decline in post-industrialism, as its conservative beliefs are fundamentally challenged by the new values and norm-settings of the above-mentioned new middle class (e.g. Bhambra, 2017; Hochschild, 2016; Williams, 2017).

This social classification of post-industrial societies has a socio-spatial component. Friedmann and Wolff (1982) introduced prominently the class-related figure of "citadel and ghetto" to characterise socio-spatial polarisation within the World City formation processes in post-industrialism. Later, Marcuse (1997) prominently complemented this socio-spatial perception with the term of the "enclave". These three socio-spatial categories within the world or global city context (i.e. citadel, ghetto, enclave) are applicable for locating the post-industrial three-class society outlined above (i.e. new middle class, underclass, traditional middle class) and are expected to play a key role in the marketisation process of new mobility services (and thus also for the constitution of the PMNS):

In post-industrial societies, the (post-industrial) "citadel" describes exclusive zones of the global city that are largely reserved for the globalised knowledge and financial economy and its representees; i.e. the ruling class (Friedmann and Goetz, 1982; Marcuse, 1997). It thus contains the network of economic and cultural infrastructures, institutions and services that are in demand by the highly qualified personnel of the globalised knowledge and financial economy and its guests (ibid.). From a traditional transport and mobility point of view, these areas represent the so-called 3D (density, diversity and design), which is a good basis for high accessibility and high-performance public transport systems (Cervero and Kockelman 1997). The regulation of participation in these zones takes place, inter alia, via economic mechanisms such as real estate prices or rents. In this regard, reference should be made to the effects of the extensively researched gentrification processes in global cities, according to which socially marginalised groups have been increasingly priced out of specific neighbourhoods in recent decades (Lees, 2000; Smith and Williams, 2013). Regarding our conceptualisation of a Premium Mobility Network Space, we assume that this is likely to cover the citadel, as this is where the new middle class as target groups of the mainly market-based providers of new mobility services tend to be localised.

In the urban shadow of the citadels, the "ghettos" remain as deportation containers for the precarious underclass (Friedmann and Goetz, 1982); i.e., those peripheralised neighbourhoods with lacking structural and social infrastructures as well as poor services, where the socio-economically and socio-culturally marginalised underclass is concentrated and excluded from the population majority. In conceptual reference to Graham and Marvin (2001), this socio-spatial polarisation, which is particularly visible in global cities, is likely to be equally reflected in the polarised image of PMNS and Mobility Network Ghettos (MNG). Here, MNG's represent those marginalised zones that are mainly bypassed by the market-based mobility service providers and that can be linked to concepts such as transport and mobility poverty (Lucas, 2012); i.e. where connectivity to public and private transport and mobility networks is weak due to the lack of infrastructure and/or high price barriers to access for residents. Following Keil and Ronneberger (1994), however, the frontiers between citadel and ghetto–and thus presumably also between PMNS and MNG–have to be understood in a dynamic relation, since the ghetto can always fall under the influence of the citadel (e.g. due to processes of gentrification).

According to Reckwitz's (2021) three-class concept outlined above, it should be emphasised that the old (traditional) middle class also (re) produces its social spaces within the global cities. However, this is on a small scale, as they tend to have their centres of life in exurban areas (ibid.). With regard to their refuges in the global cities, the suburban residential areas in the urban sprawl are particularly notable, in which traditional Fordist models of housing and living are reproducing to this day (e.g. Menzl, 2007). This refers to those largely dispersed, monofunctional residential areas with one- and two-family houses that are still oriented towards the calculable framework conditions of a prospering economy. These are–for example with regard to the observations in the field of residential self-selection (e.g. Cao et al., 2009)–always to be read as bastions of purely car-based mobility styles, insofar as private automobility is distinctively defended there socio-spatially and structurally, which is otherwise rather associated with the exurban space outside the global cities (e.g. infas et al., 2018). In distinction to the PMNS and the MNG, we therefore want to characterise this space of mobility as the Traditional Automobile Enclave (TAE). It is likely that the new mobility service providers will bypass the TAEs due its culturally inscripted form of private automobility.

2.3. Linkages of previous studies of (geographic) transport and mobility research to PMNS

When transport and mobility researchers analyse the spatial supply structures of new mobility services, it is striking that case studies are almost exclusively conducted in global (or world) cities.[1] In line with our thesis on the existence of a PMNS, this is inasmuch understandable, as the PMNS is expected to only cover prosperous global cities to a large extent. Interestingly, a cross-section of these studies also suggests a persistence of polarised supply structures that seem to follow the dichotomy of PMNS and MNG. Moran et al. (2020, 2021) observe, e.g., in the cases of San Francisco (global city status: α-) and Vienna (global city status: α-), that the service boundaries of (flexible) carsharing services are shifted by providers but are never aligned with the administrative city boundaries. Further studies indicate that this form of service placement primarily connects areas of (socio-economically and

[1] The Globalization and World Cities Research Network (GaWC, 2021). GaWC, following Jonathan Beaverstock et al. (1999), has captured this urban hierarchy in the form of a global city ranking. According to this ranking, α-cities represent the world's most powerful economic regions (e.g. London, New York, Paris, Frankfurt), β -cities medium-sized economic regions (e.g. Berlin, Copenhagen, Washington D.C.) and γ-cities smaller economic regions (e.g. Rotterdam, Antwerp) within this network.

culturally) privileged groups of people, whereas areas of marginalised groups are bypassed. Aberle (2020), for example, undertakes GIS analyses of four ride-pooling schemes in Hamburg (global city status: β+) and shows that neighbourhoods with a high proportion of social benefit recipients tend to be less frequently connected to such schemes. Clark and Curl (2016) use simple bivariate analyses to examine the station-based carsharing and bikesharing services in Glasgow (global city status: γ+) and show that people with low levels of schooling and high levels of unemployment are significantly less likely to live in the vicinity of the stations and to access the services. Goodman and Cheshire (2014) use the example of the expansion of the bicycle rental system in London (global city status: α++) to show that although some of the poorest areas of the city have been successively connected to the system, high price increases for using it have led to the exclusion of socially marginalised groups. McKane and Hess (2021), using Chicago as a case study (global city status: α), find that ridesourcing is associated with gentrified areas where rents have risen more in recent years and neighbourhoods have become whiter and more educated. Tyndall (2016) uses regression models to show that a flexible carsharing provider in ten US cities–namely: Austin (global city status: β-), Columbus (global city status: γ-), Denver (global city status: β), Miami (global city status: β+), Minneapolis (global city status: β-), New York City (global city status: α++), Portland, San Diego (global city status: β-), Seattle (global city status: β) and Washington D.C. (global city status: β+)–offers its vehicles in areas that are disproportionately populated by educated, young, employed and white residents. Finally, Stehlin and Payne (2022) examine bicycle sharing as a mesoscale infrastructure system in the US urban regions of Austin (global city status: β-), Philadelphia (global city status: β), and the San Francisco Bay Area (global city status: α-). They find that the spatial supply of bicycle sharing is limited to urban centres due to the widespread expectation of fiscal self-sufficiency and that it reproduces largely existing patterns of racialised unequal developments. This work is of particular interest because, regarding the socio-spatially fragmented supply of sharing services, it also points to substantial social problematic conditions that could be explained by the concept of splintering urbanism.

3. Methods/data

In the following analyses, we empirically deepen the understanding of spatially selective supply patterns as defined by the PMNS in the German context in two ways: First, by analysing the supply structures of new mobility services by comparing large German cities with over 300,000 inhabitants. This selection was made because studies from the German context claim that developments in the field of new mobility services are particularly apparent in larger cities around this size (e.g. Bauriedl and Wiechers, 2021). Second, by analysing the spatial supply structures of new mobility services in detail using the city of Frankfurt/Main as a case study. We selected Frankfurt/Main as a case study because it is often described as a leading city in the field of progressive developments in the field of new mobility services (e.g. bcs, 2022; Greenpeace e.V., 2017).

In the following, we first describe the methodological approaches for the city comparison (Sec. 3.1), then present the specific (socio-)spatial profile of Frankfurt/Main (Sec. 3.2), followed by the supply structures of the largest mobility service providers on-site (also in their role as dependent variable in the bivariate and multivariate analyses) (Sec. 3.3), as well as finally the (socio-)spatial criteria taken into account in the analyses in their role as independent variables (Sec. 3.4).

3.1. City typology and data

For city comparison, we categorised 23 German cities with over 300,000 inhabitants according to three city types. These are i. cities with "global city status" according to GaWC (2021), ii. "(old-industrial) structurally weak cities", e.g. in line with Kühn (2016), and iii. "average cities" as a category between economic prosperities and structural weaknesses. In total, seven cities could be assigned to the "global cities" (Berlin, Hamburg, Munich, Cologne, Frankfurt/Main, Dusseldorf, Stuttgart), five cities to the (old-industrial) structurally weak cities (Dortmund, Essen, Duisburg, Bochum, Wuppertal) and ten cities to the "average cities" (Leipzig, Bremen, Dresden, Hanover, Nuremberg, Bielefeld, Bonn, Münster, Mannheim, Karlsruhe).

For all these cities, key characteristics of the supply structures of three key types of new mobility services were recorded: i.e. for free-floating carsharing, bikesharing, and e-scootersharing. Since data for the supply is lacking transparency, the data collection was based on an extensive online media analysis as well as data inquiries with the city administrations and mobility service providers. Due to the heterogeneous variety of sources explored, the collected numbers may deviate from the actual counts of the providers.

3.2. Global city Frankfurt/main

The city of Frankfurt/Main, around 750,000 inhabitants, is regarded as one of the most important hubs of the globalised financial economy and international transportation in the network of global cities due to the presence of headquarters of numerous major banks, insurance companies and other high-value services, as well as of the renowned Frankfurt Trade Fair, the German Stock Exchange and the international Frankfurt Airport (Keil, 2011; Keil and Ronneberger, 1994; Ronneberger, 1994; Schipper, 2013). At least since the 1980s and 1990s, Frankfurt's urban policy has established an exclusive role for the city with an entrepreneurial image in the context of the growing importance of the international financial economy and the changing forms of the post-industrial division of labour (Schipper, 2014). The more recent urban development of Frankfurt has involved a new orientation whereby the city developed from a purely national to an international financial centre of the globalised economy (ibid.). Ronneberger (1994), e.g., reconstructed this development using process analysis, revealing the urban economic restructuring which ensured that all urban spaces were interpreted as land reserves and contributed towards building up the today's characteristic citadel structure.

The production of the citadel structure in Frankfurt was undertaken in the context of massive urban restructuring measures and was spatially effective in at least three respects. First, increasingly entrepreneurial urban policy, typical for Frankfurt and unique among German cities, enabled the reorganisation of central zones, primarily of the former manufacturing sector, with the aim of building and expanding high-quality office and commercial space for the global financial economy in high-rise buildings (Schipper, 2014). Second, massive state-led restructuring measures were undertaken in once "ungentrifiable working-class neighbourhoods"–e.g. Ostend or Gallus–with the aim of creating an attractive living environment for the city's new economic and cultural elites (e.g. through "*Edelsanierungen*") (Mösgen et al., 2018; Schipper and Wiegand, 2015). Third, the city established a mix of massive creative urban development and high culture promotion (e.g. in the cases of Alte Oper, Museumsufer, Römer, Neue Altstadt etc.) to ensure a feel-good climate for the city's new elites (Dzudzek and Lindner, 2013; Pratt, 2009).

This process of functional spatial re-formation in Frankfurt corresponded with a change in urban socio-demographics and socio-economics that Keil and Ronneberger, (2000) illustrate with reference to a dualised urban-regional labour market: on the one hand, a multitude of new high-skilled jobs in the financial economy and other knowledge-based services and, on the other hand, new low-wage jobs directly designed to work in gigs for the new financial and cultural elite. Against the backdrop of the establishment of the citadel structure, this process of social polarisation in Frankfurt takes place in a specific socio-spatial way, as rising land prices and rents foster displacement processes (Mösgen et al., 2018; Schipper, 2013). Frankfurt's periphery with, in some places, mono-functional satellite settlements that lack urban

amenities and public transport links (e.g. in Sossenheim, Bonames, Frankfurter Berg) increasingly functions as a container for displaced, marginalised groups (Ronneberger, 1994). The polarising concept of the citadel and the ghetto also seems to be socio-politically mirrored in Frankfurt, in that the progressive parties (Greens, Left, Liberals) are stronger than average in the gentrified urban neighbourhoods, while an above-average orientation towards the newly strengthened extreme right can be seen in the marginalised areas of the city (Mullis, 2021).

3.3. *Splintered supply structures of new mobility services in Frankfurt/main (dependent variables)*

Within this economically and culturally prosperous context of Frankfurt, an extensive placement of new mobility services has emerged in recent years. The supply structure of five major new mobility service providers is visualised in certain business area maps (Figs. 1-5). Whereas Share Now (carsharing, Fig. 2) and Lime (e-scootersharing, Fig. 5) allow almost completely free pick-ups and drop-offs of their vehicles within these areas (free-floating systems), Flinkster/Book'n'drive (carsharing, Fig. 1), Call-a-bike and Nextbike (both bikesharing, Figs. 3-4) additionally provide mainly station-based services. To capture the spatial extent of business areas and station networks we overlayed them with the georeferenced boundaries of all the 47 urban districts of Frankfurt, ranging from 3,700 to 42,000 inhabitants and usually functioning as subcentres providing private and public goods and services.

All maps clearly show the centralised tendency of the current supply coverage. However, it becomes apparent that the business areas of the five providers seems to differ in geographical coverage (ranging from 8.7 to 36.1% of the urban area) and layout. Thus, even if the five business areas differ in extent, in line with Moran (2021) it is apparent that none of them is identical to the administrative area of Frankfurt and its districts. Without exception, all five service providers cover the Central

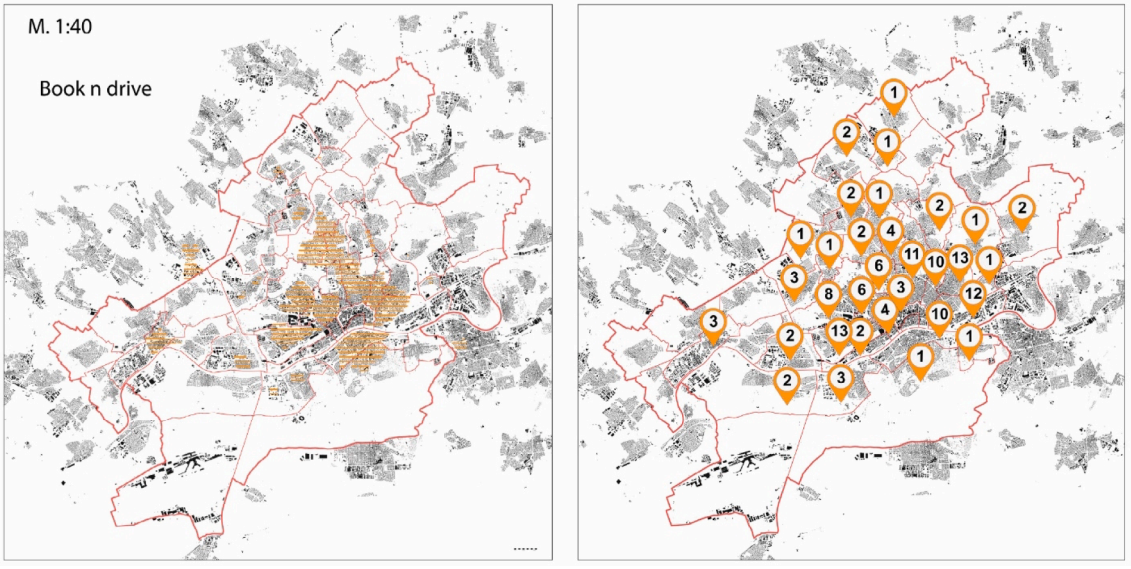

Fig. 1. Business area of the flexible carsharing scheme (left map) and positioning of the station-based carsharing service with number of stations per district (right map) of Flinkster/Book'n'drive in Frankfurt (recorded 10/2021).

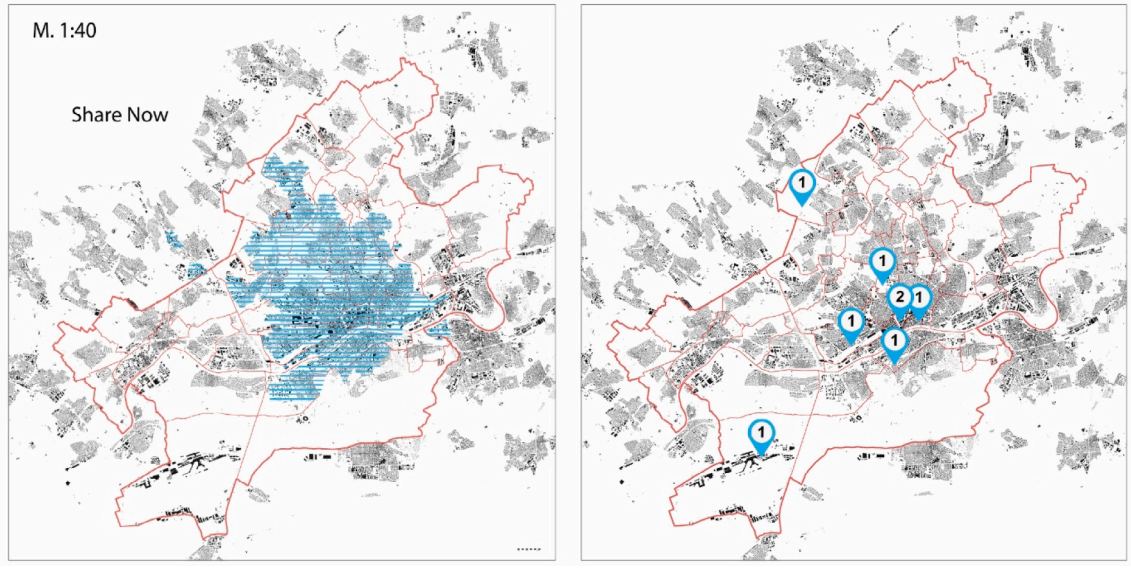

Fig. 2. Business area of the flexible carsharing scheme (left map) and positioning of the station-based carsharing service with number of stations per district (right map) of Share Now in Frankfurt (recorded 10/2021).

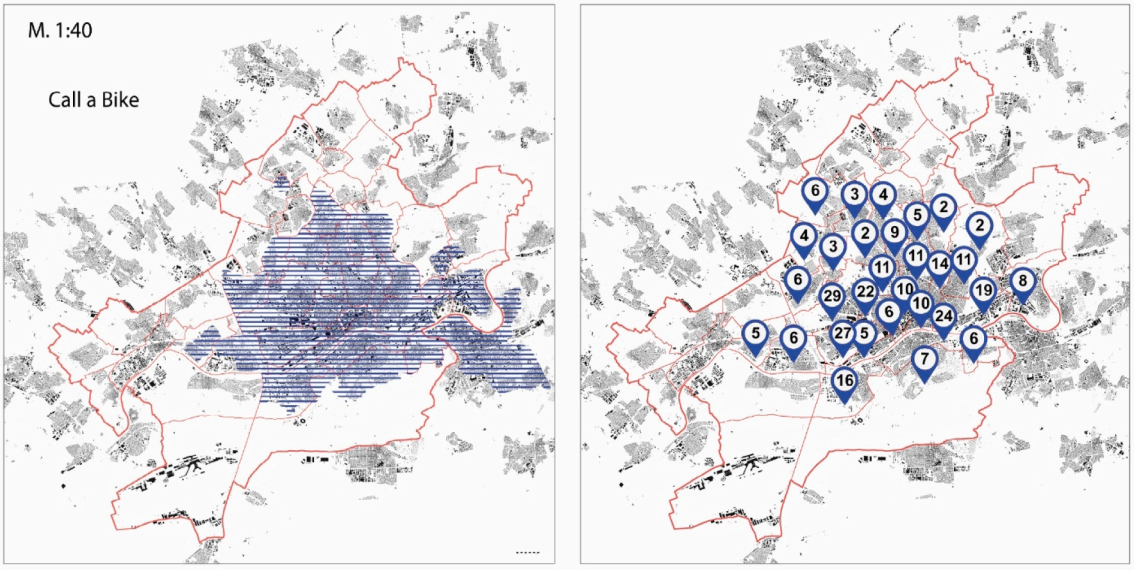

Fig. 3. Business area of the flexible bikesharing scheme (left map) and positioning of the station-based bikesharing service with number of stations/district (right map) of Call a Bike in Frankfurt (recorded: 10/2021).

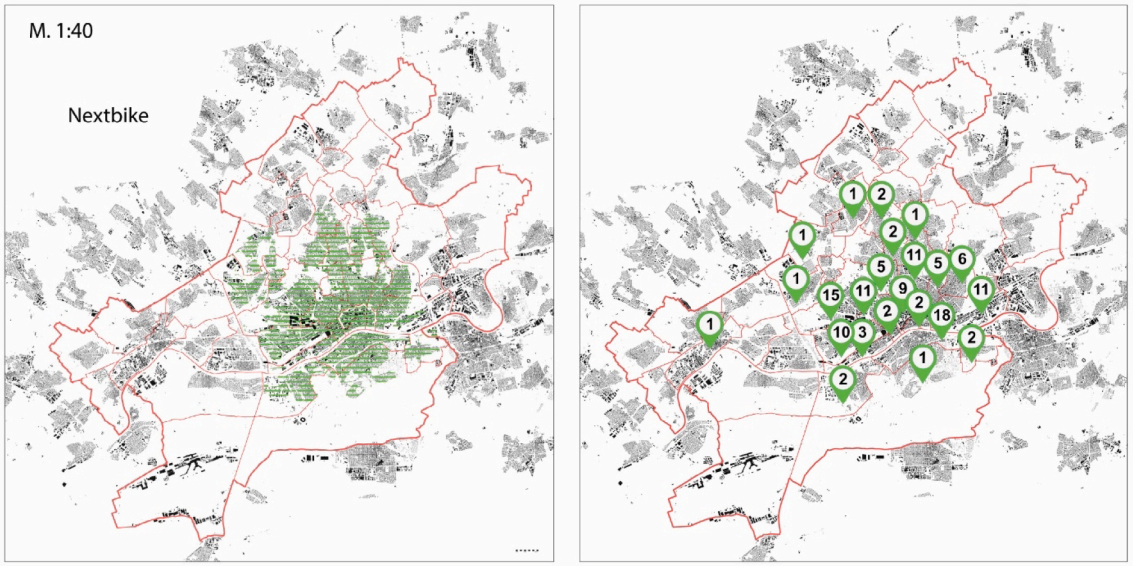

Fig. 4. Business area of the flexible bikesharing scheme (left map) and positioning of the station-based bikesharing service with number of stations/district (right map) of Nextbike in Frankfurt (recorded: 10/2021).

Business District of Frankfurt/Main. The two carsharing service providers extended to certain suburban areas which can be interpreted as part of the PMNS, since they are often located around knowledge-based R&D businesses and education centres, such as Eschborn-Süd in a neighbouring town to the north-west of Frankfurt or the university campus Riedberg in the north of the city. Furthermore, the carsharing provider Share Now operates at Frankfurt International Airport based on reserved parking lots in a big multi-story car park. This can be understood as indicating multi-scalar and intermodal travel patterns combining air travel and new mobility services (Addie 2014). In sum, these spatial patterns seem to be in line with the concepts of newly formed, gentrified inner city areas (Section 3.2) as well as privileged enclaves next to suburban business parks and international mobility hubs such as airports.

For the bi- and multivariate analyses presented in Section 4, we defined dependent variables referring to the station-based and the business-area-related supply structures. For the station-based services we calculated the metric variable indicating the district-specific station share by dividing the number of stations in the urban district by the number of all the stations of this provider in Frankfurt. For free-floating services we developed a three-point ordinal scale ranging from 1 (business area covers<20% of the district) to 3 (business area covers at least 80% of the district).

3.4. Description of independent variables

This section describes a set of indicators which we assume to have an important influence on determining the current spatial distribution of new mobility service supplies. We have mainly used open-source data published by the City of Frankfurt, which are large-scale district level data compiled for each of the 47 districts. For the analysis we selected 27 variables (Table 1) grouped into four categories: centrality, socio-

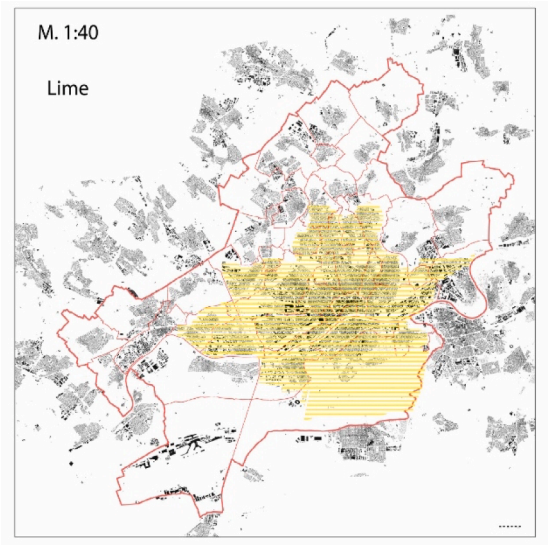

Fig. 5. Business area of the flexible e-scootersharing scheme of Lime in Frankfurt (recorded 10/2021).

demographic, socio-economic and socio-political characteristics. Centrality characteristics include settlement density, the types and purchase price of housing, and proximity to Frankfurt city centre by public transport in terms of travel time and fare. We assume that new mobility services can potentially be considered as a way of improving accessibility in low-density districts less well-served by public transport. Socio-demographic factors include gender, age groups and immigration background of residents as well as household composition. The combination of these variables reveals certain trends of residents' profiles per studied district. It is widely recognised that certain demographic groups (e.g. young adults/single households) are most likely to opt for new mobility services (McKane and Hess, 2021). Socio-economic characteristics are also informative variables influencing people's capacity to make a choice between different travel modes. Employment rate, income level and dependency on social security benefits are included as they often determine the affordability of private cars, which has a knock-on effect on people's mobility choices. Finally, residents' voting characteristics are considered since supporters of the Green party in Germany have a strong interest in achieving net-zero emissions, while supporters of rather right-wing parties such as the CDU and AfD are less committed to environmental goals concerning their mobility.

4. Findings

This section analyses the supply structures of new mobility services in Frankfurt related to the socio-spatial and spatial-structural variables of the four categories outlined above (i.e. i. centrality characteristics, ii. socio-demographic characteristics, iii. socio-economic characteristics, and iv. socio-political characteristics). First, we use bivariate correlation

Table 1
Overview of applied indicators for the city districts.

District indicators	Description of district indicator	Year
Centrality characteristics		
Settlement density	No. of residents per sq.km	2019
Terraced, semi-/detached houses including flats	No. of dwellings including flats within buildings	2019
Purchase prices of newly built apartments	Average prices for purchasing flats within newly built apartment blocks in euros per square metre	2019
PT travel time to main station in minutes	Minimum travel time from the centroid* of each district to main station using public transport (PT) in minutes. Based on the weekday peak period (between 7:30 and 8:30 am on Tuesdays as a typical working day) the upper limit of the peak period: arrival time 8:30 am.	2017
PT travel fare to city centre	Public transport fare for travelling from the main station to the centroid of each district based on the PT minimum travel time	2017
Socio-demographic characteristics		
Women	Women (%)	2019
Men	Men (%)	2019
People without migration background	People without migration background (%)	2019
People with migration background	People with migration background (foreign citizens and people with at least one foreign parent) (%)	2019
Foreigners	Foreigners (%)	2019
Young adults	Young adults between 18 and 29 (%)	2019
Middle-aged	Middle-aged adults between 30 and 64 (%)	2019
Seniors	Seniors, aged 65 years and older (%)	2019
Single households	Single households (%)	2019
Couple households without children	Couple households without children (%)	2019
Socio-economic characteristics		
Employment rate	Employed people (%)	2019
Minijob rate	People with minijobs (earning not more than €450 per month) (%)	2019
Full-time employment rate (low incomes)	Employed people on a full-time basis with low incomes (<2,000 EUR) (%)	2019
Full-time employment rate (middle and high incomes)	Employed people on a full-time basis with middle and high incomes (>2,000 EUR) (%)	2019
Unemployment rate	Unemployed people (%)	2019
Unemployment rate with social security beneficiaries	Unemployed people receiving social security benefits (SGB II/Hartz IV) (%)	2019
Socio-political characteristics		
CDU supporters	Christian Democratic Party (CDU) voters (centre-right) (%)	2016
SPD supporters	Social Democratic Party (SPD) voter (centre-left) (%)	2016
Green supporters	Voters of Alliance 90/the Greens (centre-left) (%)	2016
FDP supporters	Free Democratic Party (FDP) voters (centre-right) (%)	2016
Left supporters	The Left voters (left-wing) (%)	2016
AfD supporters	Alternative for Germany (AfD) voters (right-wing) (%)	2016

Sources: City of Frankfurt (2021), Stadtteile FFM, except for indicators no. 3 and 4:
Source for indicator 3: Immobilien Scout GmbH, 2019.
Source for 4: https://www.rmv.de, timetable for local/regional public transport from 2017 – the centroid of each district was calculated using the district geofence file and a specific address for the centroid was provided (see Otsuka et al., 2019).

models to find correlations between the supply structures of the mobility services and the single variables (Sec. 4.1). Second, linear and logistic regression models with preceding exploratory factor analyses are applied (Sec. 4.2). In this way, highly correlated socio-spatial and spatial-structural variables are bundled into corresponding factors, which are subsequently analysed synchronously with regard to the supply of the new mobility services.

4.1. Supply structures of new mobility services at the inter-city level of German cities with more than 300,000 inhabitants

The comparison of the 23 German cities with regard to the supply structures of the new mobility service types recorded illustrates a pattern of quality differences by city type. Concerning this, Fig. 6 shows the number of providers on the y-axis and the supply densities on the x-axis within the cities. The overarching pattern is that the cluster of German global cities tend to have the highest number of providers and highest density of supply for all three mobility service types. In contrast, the cluster of "average cities" tend to have significantly lower numbers of providers and densities of supply. Finally, the five structurally weak old-industrial cities tend to deviate from the dynamic development trends and have the lowest supply densities or even in some cases no mobility service supply.

Moreover, Fig. 6 provides additional information in superscript form on the German cities with the major railway stations and airports; i.e. based on the official number of rail passengers and air passengers. In addition to the top positions of supply in the case of new mobility services, the German global cities also hold - with one exception - all the top positions in this case, which corresponds to the concept of a PMNS.

4.2. Supply structures of new mobility services at the intra-city level in the case of Frankfurt/Main (Bivariate Analyses)

For the analysis of the socio-spatial positioning of mobility services

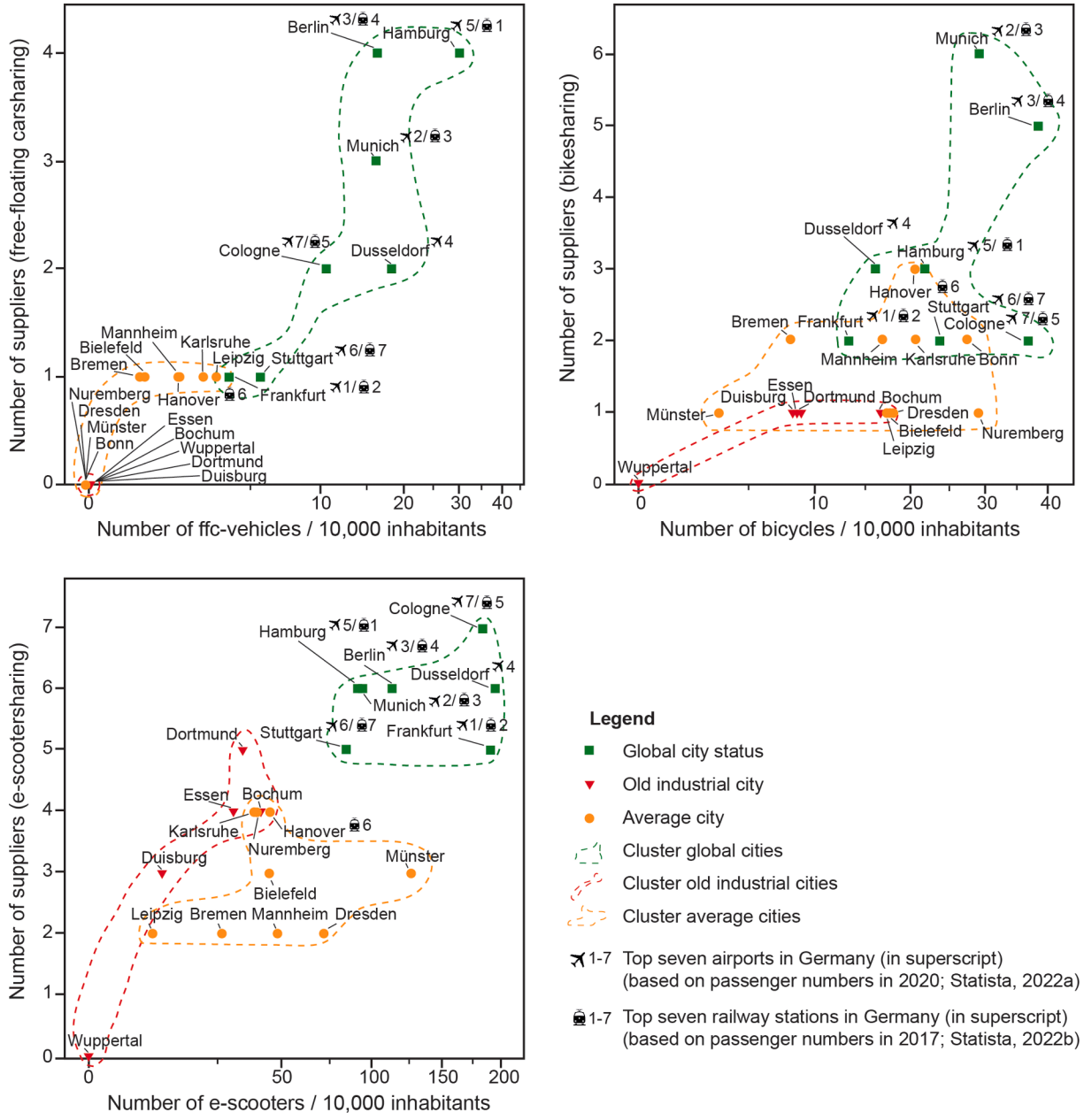

Fig. 6. Number of providers of the three service types and supply density in the 23 German cities (clustered by global city status, old industrial city and average city) (own illustration; recorded 11/2021).

Table 2
Correlation between spatial supply structures of free-floating mobility services and (socio-)spatial characteristics of the districts (Spearman's rank correlation coefficient).

	Carsharing		Bikesharing		E-Scooter-sharing
	Flinkster/Book'n'drive	ShareNow	Call-a-bike	Nextbike	Lime
Centrality characteristics					
Settlement density	0.240	0.436**	0.515**	0.518**	0.481**
Terraced, semi-/detached houses including flats within houses	-0.365*	-0.689**	-0.826**	-0.732**	-0.827**
Purchase prices of newly built apartments *(in EUR/m²)*	0.501**	0.798**	0.686**	0.827**	0.672**
PT travel time to main station in minutes	-0.339*	-0.508**	-0.636**	-0.567**	-0.619**
PT travel fare to city centre	-0.045	-0.425**	-0.380**	-0.457**	-0.391**
Socio-demographic characteristics (2019)					
Women	0.509**	0.308*	0.082	0.221	0.025
Men	-0.460**	-0.227	0.008	-0.147	0.064
People without migration background	0.540**	0.146	0.064	0.139	0.008
People with migration background	-0.353*	-0.274	-0.368*	-0.361*	-0.331*
Foreigners	-0.385**	0.085	0.267	0.109	0.305*
Young adults (18–29)	0.203	0.569**	0.562**	0.534**	0.555**
Middle-aged (30–64)	0.292*	0.388**	0.541**	0.468**	0.590**
Seniors (over 65)	-0.093	-0.255	-0.226	-0.231	-0.280
Single households	0.432**	0.651**	0.784**	0.721**	0.784**
Couple households without children	-0.191	-0.347*	-0.469**	-0.393**	-0.519**
Socio-economic characteristics (2019)					
Employment rate	0.405**	0.308*	0.394**	0.378*	0.463**
Minijob rate	-0.490**	-0.523**	-0.498**	-0.549**	-0.521**
Full-time employment rate (low incomes)	-0.627**	-0.491**	-0.298*	-0.443**	-0.259
Full-time employment rate (middle and high incomes)	0.582**	0.606**	0.417**	0.588**	0.367*
Unemployment rate	-0.575**	-0.358*	-0.169	-0.341*	-0.133
Unemployment rate with social security beneficiaries (SGB II/Hartz IV)	-0.579**	-0.375*	-0.171	-0.341*	-0.134
Socio-political characteristics (based on elections in 2016)					
CDU supporters	-0.150	-0.425**	-0.517**	-0.355*	-0.560**
SPD supporters	-0.237	-0.201	-0.029	-0.199	-0.017
Green supporters	0.650**	0.646**	0.447**	0.595**	0.394**
FDP supporters	0.308*	0.599**	0.438**	0.565**	0.363*
Left supporters	0.191	0.525**	0.572**	0.454**	0.557**
AfD supporters	-0.682**	-0.709**	-0.532**	-0.677**	-0.436**

**p <.01; *p <.05.

in Frankfurt/Main with free-floating businesses, the Spearman's rank correlation coefficient was calculated with regard to the ordinally scaled dependent variables (Table 2). In the analysis of mobility services offering a station-based supply, Pearson's correlation analysis was calculated with regard to the metrically scaled variables with free-floating services (Table 3). Noticeably, the two different market models consistently show similar directions in terms of correlations with the spatial variables within the four categories:

Centrality characteristics: All observed mobility services correlate with high-density urban areas, particularly in districts which offer higher-standard flats in relatively upmarket areas, given strong positive correlations between the purchase price for new flats and the presence of all free-floating service providers (e.g. free-floating Nextbike 0.827). In contrast, suburban areas characterised by lower density and the presence of semi-detached or detached houses show strong negative correlations with all providers (e.g. free-floating Lime -0.827). Districts located further from the main station are served by less new mobility services and there are significant negative correlations between travel time to the station and supply from all providers (e.g. free-floating Call-a-bike -0.636).

Socio-demographic characteristics: Correlations with socio-demographic characteristics are still difficult to identify with regard to the supply locations. However, districts characterised by people in single households, young adults and residents without a migration background are well served by the new mobility services. Strong positive correlations are observed with the proportion of single households (e.g. free-floating Call-a-bike or Lime 0.784), young adults and middle-aged persons (e.g. free-floating ShareNow 0.569; free-floating Lime 0.590) and those without a migration background (free-floating Flinkster 0.540). Gender plays a less prominent role in the current supply patterns of new mobility services, except for the supply of free-floating Flinkster in those areas with a higher share of women (0.509).

Socio-economic characteristics: Socio-economic characteristics appear to play a much stronger role in the placement of service supply networks. Districts resided in by economically prosperous groups with middle or high incomes benefit from the current supply structure, which is evident from their strong positive correlations (e.g. station-based Nextbike 0.622). Vulnerable groups, represented by the following three conditions: low-income groups, unemployed persons or social security beneficiaries (HARTZ IV), seem to be disconnected from supplies, given their strong negative correlations (e.g. free-floating Flinkster: -0.627, -0.575 and -0.579, respectively). Also, certain districts with a (higher) proportion of minijob employment are not well-connected even with free-floating and station-based bikesharing or e-scootersharing services which are cheaper than carsharing, given their strong negative correlations (e.g. station-based Call-a-Bike -0.665, free-floating ShareNow -0.523; free-floating Lime -0.521).

Socio-political characteristics: It can be seen that the providers of new mobility services directly target people with a specific political orientation. According to voting results from the local election in Frankfurt, strong positive correlations are found between the share of supporters of the Green party and all the service providers, particularly with carsharing supplies (e.g. station-based Flinkster 0.691). Also, this direction is echoed by the strong positive correlations with Left party supporters (e.g., free-floating Call-a-bike 0.572). In contrast, the proportions of AfD (right-wing party) and CDU (conservative party) voters are negatively correlated with carsharing (e.g. free-floating ShareNow -0.709 for AfD) and bike/e-scootersharing services (Nextbike -0.517/ Lime -0.560 for CDU).

Table 3
Correlation between spatial supply density of station-based mobility services and (socio-)spatial characteristics (Pearson's correlation analysis).

	Carsharing	Bikesharing	
	Flinkster	Call-a-bike	Nextbike
Centrality characteristics			
Settlement density	0.537**	0.426**	0.370*
Terraced, semi-/detached houses including flats within houses	-0.542**	-0.646**	-0.555**
Purchase prices of newly built apartments *(in EUR/m²)*	0.595**	0.648**	0.629**
Public transport supply	-0.440**	-0.565**	-0.543**
PT travel time to main station by PT in minutes	0.344*	0.374*	0.357*
PT travel fare to city centre	-0.157	-0.376**	-0.420**
Socio-demographic characteristics			
Women	0.126	0.112	0.093
Men	0.083	0.124	0.081
People without migration background	0.239	0.124	0.203
People with migration background	-0.233	-0.231	-0.283
Foreigners	0.027	0.193	0.075
Young adults (18–29)	0.312*	0.438**	0.364*
Middle-aged (30–64)	0.311*	0.310*	0.286
Seniors (over 65)	-0.218	-0.241	-0.240
Single households	0.523**	0.581**	0.559**
Couple households without children	-0.286	-0.272	-0.302*
Socio-economic characteristics			
Employment rate	0.624**	0.522**	0.568**
Minijob rate	-0.593**	-0.665**	-0.639**
Full-time employment rate (low incomes)	-0.417**	-0.395**	-0.445**
Full-time employment rate (middle and high incomes)	0.553**	0.580**	0.622**
Unemployment rate	-0.293	-0.295*	-0.311*
Unemployment rate with social security beneficiaries (SGB II/Hartz IV)	-0.311*	-0.314*	-0.329*
Socio-political characteristics			
CDU voters	-0.383*	-0.334*	-0.231
SPD voters	-0.152	-0.194	-0.308*
Green voters	0.691**	0.593**	0.654**
FDP voters	0.232	0.426**	0.443**
Left voters	0.415**	0.339*	0.280
AfD voters	-0.581**	-0.533**	-0.594**

**p <.01; *p <.05.

4.3. Supply structures of new mobility services at the intra-city level in the case of Frankfurt/Main (Multivariate Analyses)

4.3.1. Explorative factor analyses

In order to densify the set of variables and reveal its underlying dimensions, an explorative factor analysis is applied in this section (principal component analysis, varimax rotation) (see Table 4). In preparation, we had to exclude eleven variables ("voters SPD", "voters CDU", "district's share of seniors", "district's share of middle-aged (30–64 yrs old)", "district's share of young adults (18–29 yrs old)", "district's share of Germans with migration background", "district's share of Germans without migration background", "district's share of men", "district's share of women", "travel fare to the city centre", and "public transport supply") due to insufficient communality values and/or miserable measures of sampling adequacy (MSA $\leq$ 0.5). As a result, three factors with an Eigenvalue higher than 1 were extracted that explain 76.1% of the variance.

The first factor, named *Precarious Spatial Patterns*, with an Eigenvalue of 5.1, is characterised by high positive loadings of variables such as unemployment, share of low-income households, share of foreigners and share of the far-right party AfD in the last local election. Furthermore, high negative loadings were found for the share of people without a migration background, share of medium- and high-income households and voting for the Greens at the local elections. Consequently, this factor bundles the characteristics of marginalised social areas, which primarily house a poor and excluded population.

Table 4
Results of the principal component analysis.

	Precarious Spatial Patterns (Factor 1)	Progressive Urban Patterns (Factor 2)	Sumptuous Urban Patterns (Factor 3)
Unemployment rate	0.88		
Unemployment rate with social security beneficiaries	0.87		
Full-time employment rate (low income)	0.84		
Foreigners	0.75		
People without migration background	-0.74		
Single households		0.79	
Couple households without children		-0.77	
Left supporters		0.75	
Employment rate		0.73	
Terraced, semi-/detached houses including flats within houses		-0.65	-0.52
Settlement density		0.63	
PT travel time to main station by PT in minutes		-0.62	-0.51
Green voters	-0.52	0.57	
FDP voters			0.91
Purchase prices of newly built apartments *(in EUR/m²)*		0.53	0.76
Full-time employment rate (middle and high incomes)	-0.61		0.72
AfD voters	0.51		-0.62
Minijob rate			-0.62

The second factor, named *Progressive Urban Patterns*, which shows an Eigenvalue of 4.6, is characterised by positive loadings for the share of single households, voting preferences for the Left and Green parties as well as high-density and expensive residential areas. The negative loadings for the share of houses in low density areas and distance to the main stations confirm this orientation towards inner-city neighbourhoods. Thus, this factor bundles ideal-typical urban characteristics that stand for general progressiveness.

The third factor (Eigenvalue of 4.0), *Sumptuous Urban Patterns*, shows a high representation of indicators related to affluence such as high average real estate prices and an above-average share of medium- and high-income households. Furthermore, it is characterised by high loadings with the share of people representing a liberal and non-conservative political orientation. Lastly, this factor shows an inner-city orientation, as well (cf. negative loadings for share of one- and two-family houses and travel time to main station).

4.3.2. OLS regression models estimating district-specific station share

Next, the extent to which these factor variables explain the distribution of new mobility offerings across Frankfurt's districts was examined. To this end, three linear OLS regression analyses were conducted for stationary supply structures (see Table 5). The number of bikeshare or carshare stations per city district was applied as dependent variables for each provider.

For the first model, explaining the district-specific station share of the station-based carsharing provider-cooperation between Book'n'drive and Flinkster, a negative impact of factor 1 ("Precarious Spatial Patterns") and a positive impact of factors 2 and 3 ("Progressive Urban Patterns" and "Sumptuous Urban Patterns") were found, all significant at least at the 1%-level. For the second model, estimating the station district-specific share of Call-a-bike bikesharing stations, the positive

Table 5
Linear regression to estimate the district-specific station share of selected mobility service providers.

	station share Flinkster / Book'n'drive (Beta)	station share Call-a-bike (Beta)	station share NextBike (Beta)
Precarious Spatial Patterns	**-0.317****	-0.154	**-0.232***
Progressive Urban Patterns	**0.651*****	**0.519*****	**0.518*****
Sumptuous Urban Patterns	**0.296****	**0.537*****	**0.509*****
Adjusted R^2	*0.585*	*0.551*	*0.552*

*p <.05, **p < 01, ***p <.001.

influence of progressive and elitist/wealth orientations can be confirmed, whereas the precarious orientation did not show a significant influence. For the third model, explaining the district-specific share of NextBike bikesharing stations, all three expected influences can be confirmed again at least at the 5%-level. Districts with high values for factor 1 show a low density of stations, districts with high values for factors 2 and 3 (progressive and elitist/wealth) show high station densities. All three models show highly acceptable model fits (adjusted $R^2 >$ 0.5).

In sum, for station-based mobility services, the main influences found in the bivariate analyses could be confirmed: precarious spatial patterns and economic disadvantage are associated with no supply of these services, whereas progressive and sumptuous urban patterns are accompanied by a rather high standard of new mobility service supply.

4.3.3. Binary logistic regression models estimating extent of service areas

Complementing the linear regression analyses, we conducted binary logistic regression analyses to explain the extent of free-floating service areas of all five of the mobility service providers analysed. As the dependent variable we chose for all five models "service area encompasses urban district at least partially". The variable can take two values, i.e. no (0) and yes (1). Independent variables are again the three factors derived from the explorative factor analysis (Table 4). For factors 2 ("Progressive Urban Patterns") and 3 ("Sumptuous Urban Patterns"), the results confirm the positive impact from the OLS models for district-specific station share at least at the 5%-level, whereas the negative impact of precarious orientation can only be confirmed for the service area extent of Flinkster/Book'n'drive (Table 6). Model fits again show highly acceptable values (Cox & Snell $R^2 > 0.4$, Nagelkerkes $R^2 > 0.6$). An explanation for the lack of impact of the precarious orientation factor might be the relatively extensive layout of many urban districts comprising both privileged and precarious neighbourhoods.

5. Discussion and conclusions

Given the current discourse on the reflexive socio-ecological self-transformation of post-industrial (service-based) societies resulting from a critical discussion of their fossil-energy reliance, this study explores the characteristics of the spatially selective supply structures of new mobility services. This work is of importance e.g. with regard to the "sustainable mobility paradigm" (Banister, 2008), as new mobility services are given a high priority in this respect: Discursively, they are structurally negotiated as part of a transition process from private automobility, which is criticised as 'ecologically unsustainable', towards multimodality, which is stylised as 'ecologically sustainable', in that mobility services represent the always flexible use of different mobility options instead of exclusive car use (e.g. Geels, 2012). However, through the theoretical lens of splintering urbanism (Graham and Marvin, 2001), concerns arise that instead of a ubiquitous supply of new mobility services, a Premium Mobility Network Space (PMNS) is emerging from the supposedly reflexive socio-ecological self-transformation; i.e. an exclusive supply of interconnected mobility services within the intra- and inter-regional social and action spaces of the bourgeois elites of post-industrial societies in the global north. Following Graham and Marvin (2001), the market-based planning, organisation and implementation of such services are likely causally responsible for a socio-spatially selective supply practice. And although the services may be promoted with slogans around 'sustainability', they are not distributed everywhere by the service providers, but within a target group's environment. Following on from this, the present study aims at tracing possible strategic (target group-centred) analyses and decision-making processes of the providers by exploring and identifying recognisable patterns in the supply structures. In view of the empirical findings and in the light of reflections on splintering urbanism, this study explores spatial patterns in three ways; i.e. i. based on a city comparison of supply structures of new mobility services in Germany and ii. by means of in-depth analyses of supply structures using the case study of the city of Frankfurt/Main:

First, it seems that a PMNS is emerging inter-regionally through the economically prosperous global city network, i.e. the inter-regional network of cities where international capital powerfully converges in the shape of financial, service and control relations. In a multitude of recent studies, it has been shown that concrete apparatuses have materialised within this network by means of a space of flows (excellence-oriented educational institutions, high-priced gastronomy, and other sophisticated services such as large museums, theatres, auditoriums, etc.). Insofar the space of flows refers to people's physical mobility, the underlying PMNS can be imagined as an interconnected supply structure of mobility services across the global city network, i.e. i. high-speed transport (airplanes, high-speed trains, etc.) enabling mobility between the prosperous cities, and ii. new local mobility services enabling highly spontaneous and situational mobility in precisely those locations. Our analysis of the supply structures of new mobility

Table 6
Logistic regression for estimating local supply structures of free-floating new mobility services.

	ShareNow		Flinkster / Book'n'drive		Call-a-bike		NextBike		Lime	
	OR	CI	OR	CI	OR	CI	OR	CI	OR	CI
Precarious Spatial Patterns	0.32	0.07; 1.43	**0.13***	0.024; 0.717	3.73	0.620; 22.50	0.36	0.06; 2.25	0.73	0.09; 5.93
Progressive Urban Patterns	**18.93***	1.92; 187.10	**3.65***	1.19; 11.24	**40.72****	3.04; 545.59	**37.95****	2.39; 602.51	**241.44****	5.56; 10484.32
Sumptuous Urban Patterns	**24.07****	2.60; 222.97	**5.95***	1.50; 23.64	**29.25****	2.38; 359.46	**50.23****	2.90; 869.25	**18.53***	1.94; 176.85
Cox & Snell R^2	*0.567*		*0.41*		*0.59*		*0.61*		*0.63*	
Nagelkerkes R^2	*0.757*		*0.658*		*0.789*		*0.815*		*0.847*	
Correctly predicted (in %)	*87.0*		*89.1*		*93.5*		*91.3*		*93.5*	

*p <.05, **p < 01, ***p <.001.

services in the German city comparison revealed that a high-quality supply of key services (free-floating carsharing, bikesharing, e-scootersharing) can only be found in the seven German global cities. In these global cities, we have also found the best-performing long-distance train stations and airports, to which the new mobility services are seamlessly connected. By contrast, the old industrial, structurally weak cities in particular have a decidedly weak range of mobility services, or in some cases none at all.

Second, within a global city itself, the PMNS grounded on the new local mobility services is by no means organised along the city's or city-region's political-administrative boundaries. Of relevance here are rather the dynamically shifting boundaries of the – in conceptual reference to Friedmann and Wolff (1982) – post-industrial citadels, i.e. the social and action spaces reserved for the bourgeois elites. By using the case of Frankfurt, the bivariate correlation models and the multivariate regression models of supply structures and socio-spatial characteristics illustrate this in an ideal-typical way. Despite differences between the business area boundaries of the specific mobility service providers, the supply structures correlate positively, without exception, with the following social space components: i. central locations (i.e. high density and multifunctionality, high purchase prices for new buildings, proximity to the central station and Central Business District), ii. socio-demographically and -economically privileged social spaces (i.e. areas with high proportions of young and middle-aged people, German origin, full-time employment, high income), and iii. socio-politically progressive and/or liberal social spaces (i.e. high proportions of green, left-wing and economic liberal voters). Although the providers of new mobility services present themselves as the bearers of sustainable everyday mobilities; however, our analyses show clearly that these services merely target the post-industrial elites in the citadels of the global cities as a pool of potential customers.

Third, in the course of PMNS production, further spaces beyond that mobility network emerge, which we have called mobility network ghettos (MNGs) and traditional automobile enclaves (TAEs) in the theoretical part of this study. These are incidental spatial productions that emerge from the direct bypassing of the social and action spaces of the marginalised underclass and also the traditional middle class by the mobility service providers. With regard to our bivariate and multivariate analyses, this can be described as follows:

- The first form of bypassing with the supply of new mobility services concerns the social spaces of the marginalised underclass: High negative correlations of supply structures of new mobility services were found with i. geographically peripheral locations far away from the city centre, ii. disadvantaged socio-demographic and socio-economic groups (high proportions of unemployed and welfare recipients, low incomes, higher proportion of persons with a migration background or foreign nationality), as well as iii. socio-political zones with higher proportions of people with far-right orientations. Consequently, the analyses clearly show that (market-based) developments in the field of new mobility services correspond to the socio-spatial production of MNG's; i.e. an economic practice that structurally produces immobilities of marginalised people by eliminating them as potential consumers and not connecting them to new progressive mobility network structures.
- The second form of bypassing by the new mobility service providers concerns the social spaces of traditional groups. By using the term of TAE we highlighted those dispersed, monofunctional and more affluent middle-class detached housing estates that are traditionally associated with private automobility and where alternatives to the automobile are hard to find in any case (see e.g. Cervero and Kockelman, 1997). In particular, this is indicated by the findings of the bivariate correlations; e.g. negative correlations with terraced and (semi-)detached housing structures, long distances to public transport stations, high fares to the main station, conservative voting patterns. The use of the term enclave instead of ghetto should be interpreted less socio-economically than socio-culturally, as it is the traditionally suburban "Automobil-Eigenheim-Ensemble" (Rammler, 2008) that is discursively associated with correspondingly conservative lifestyles. In this respect, it may be assumed that new mobility service providers bypass the social spaces of traditionalists not only because of Suburbia's sprawling character, but possibly also because alternatives to private automobility might be rejected there. Regarding this, the TAE might be interpreted as a conservative bastion from which the traditionally existing mobility networks based on the hegemonic system of private automobility receive their support within the population.

The findings of our study provide overarching evidence that any sustainability goals associated with new mobility services are subverted when the services are inscribed in a PMNS. Instead of offering a viable alternative to private automobility, the outcome is a socio-spatially exclusive service for post-industrial elites. In many respects, this PMNS seems to be incompatible with what the Sustainable Mobility Paradigm is all about. The social dimension of sustainability is left untouched as the social spaces of the socially marginalised underclass, which are anyway negotiated in a context of 'transport poverty' (Lucas et al., 2016), are left unconnected to new mobility services. In this case, 'transport poverty is reproduced in the guise of the new' (Groth, 2019). Moreover, the environmental dimension of sustainability runs the risk of being undermined because, first, new mobility services are embedded into a distance-intensive system of inter-regional mobilities, acting as regional feeders at intermodal interfaces (e.g. at airports or long-distance train stations); so the negative effects on climate are estimated to be much higher than for exclusive car use (see e.g. Heinen and Mattioli, 2019). Second, existing regional multimodal spatial structures are provided with further multimodal structural moments in the course of implementing new mobility services, whereas dispersed spatial structures of the traditional middle class tailored to the private car remain without an alternative. This may lead to substitution effects with climate-impacting consequences, for example by replacing active transport with e-scootersharing or carsharing (e.g. Reck et al., 2022).

Methodologically, the findings may be criticised as being rapidly outdated with regard to the dynamics in the field of new mobility services, since business areas and/or provider structures are constantly changing (e.g. since our research, some providers have changed their name due to restructuring or being acquired by other companies). However, under the conditions of market-based developments, the providers of new mobility services have a strong tendency to orient themselves to superordinate socio-spatial developments, as we were able to show with our study. Consequently, the form of the PMNS is expected to remain consistent with the form of the post-industrial citadel – even under changed provider names – and the correlations found in this paper are also likely to be similarly found in future studies.

This leads to the other request why the providers of new mobility services still designate partially different business areas (e.g. why Call-a-Bike is to be found in the city centre of Offenbach or Book'n'Drive and Nextbike in the industrial park on the west side of the city of Frankfurt). These issues cannot be ultimately answered by our analysis, as on the one hand it provides rather little information about the potential exclusive contracts with preferred customers (e.g. large companies on the outskirts of the city), and on the other, the underlying form of ownership strcutures along with specific firm strategies could be a decisive factor (see also Stehlin et al. 2021). In future research studies, this could be explored in more detail by explicitly interviewing the providers (e.g. in the form of in-depth qualitative interviews with regard to their supply strategies).

A last criticism may concern general statements being derived from analyses based on a limited empirical sample from Germany, which could impact the applicability of our conclusions to other regional contexts. However, Germany, with its seven cities, is highly embedded in the global city network. It is therefore to be assumed that the patterns

we found in Germany also continue in a similar form in other countries. In addition, similar observations have been already made in the global cities of other states in the global north. Future studies could explicitly start from this thesis and – if the corresponding resources are available – could explicitly define the PMNS including inter-regional transport modes (express trains, airplanes, etc.).

In conclusion, the impression remains that the sustainability attributions that are discursively produced around the supply of new mobility services turn into their opposite. The suspicion arises that a market-based development of sustainable mobilities is only capable of producing socio-spatially fragmented supply structures for the benefit of a (pretentious) new middle class; but never of producing the spatially ubiquitous solution that would be necessary for collective sustainable everyday mobilities in the sense of reflexive modernisation. A new escalation of today's class struggles in the field of the ecologisation of everyday mobilities is predetermined if the new middle class stylises their lifestyles as superordinate maxims, disregarding the fact that, socio-spatially, the underlying apparatuses are exclusively offered to them by the market-based providers.

CRediT authorship contribution statement

Sören Groth: Conceptualization, Methodology, Validation, Formal analysis, Resources, Visualization, Project administration, Data curation, Software, Supervision, Writing - original draft, Writing - review & editing. **Thomas Klinger:** Conceptualization, Investigation, Methodology, Data curation, Formal analysis. **Noriko Otsuka:** Conceptualization, Methodology, Data curation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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