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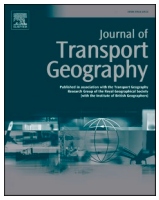

Towards an equity-centred model of sustainable mobility: Integrating inequality and segregation challenges in the green mobility transition

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ABSTRACT

Urban planners and transportation policy makers around the world are proposing initiatives for greener mobility, particularly by promoting higher urban development densities, active transport modes, and non-auto access to destinations. This Special Issue engages critically with the sustainable mobility and 15-Minute City concepts by outlining an Equitable Sustainable Mobility Model that integrates non-auto accessibility improvements with key daily activity destinations to establish a wider discussion on urban structure, segregation, equity and mobility. The papers collected in this Special Issue reveal that sustainable mobility solutions are only partial when detached from the underlying mechanisms of residential sorting and spatial patterns of daily activity spaces. An equitable shift towards greener mobility needs to (1) address rising levels of residential segregation by promoting neighbourhood-level mixed-income housing, (2) radically shift urban space from automobility to different greener forms of mobility, (3) address not only neighbourhood specific, but also metropolitan-level access challenges to key activity places, (4) focus on integrating broadly accessible and affordable travel modes, particularly active travel (walking and cycling) and public transit, and (5) develop e-mobility solutions that are accessible to diverse user needs and offer flexible inter-neighbourhood coverage.

1. Focus of the special issue

Reducing personal car use has been identified as one of the key solutions to reducing global greenhouse emissions and limiting global warming to a targeted 1.5° degrees Celsius compared to pre-industrial levels (IPCC, 2023). From Paris to Seoul, Los Angeles to Pune, and Santiago to Dar es Salaam, cities rally behind a greener urban mobility future by implementing policies and investments that aim to shift the 20th century legacy of individual automobility towards a greater share of greener transportation modes in the 21st century: public transit, walking and cycling (Newman and Kenworthy, 1999; Banister, 2011). In the planning realm, this shift involves investing into bus and rail transit services; implementing multi-modal ticketing systems; building new and redesigning existing streets to expand transit-, biking-, walking- and micro-mobility capacity; implementing vehicle sharing programs (for bikes, electric scooters and cars alike); and coordinating land-use and transportation plans to nudge new construction activity to locate closer to existing population concentrations and public transport connections (Ballo et al., 2023; Sadik-Khan and Solomow, 2017). In the policy realm, the sustainable mobility shift further involves the introduction of road tolls; increased parking fees; tax subsidies for electric vehicles; and incentives for behaviour change to increase the social and spatial penetration of sustainable modes of mobility (Altshuler and Davis, 2018; Lowe et al., 2022).

Progressive climate policies, however, are often challenged by inherited urban forms and social structures, entrenched in deep path-dependency and lock-ins towards personal automobility from the past. As car ownership grew in post-World War II decades, a myriad urban plans and policies fostered solutions for car-oriented built environments by investing into road and parking infrastructure, faster travel speeds and low-density neighbourhoods premised around personal car use (Fishman, 2008; Anciaes and Jones, 2020). The now widely familiar outcome—a sprawling metropolis—poses sever challenges to the Green Mobility shift since walking, cycling and public transport use require more compact, high-density, mixed-use built environments (Jones, 2014; De Vos and Witlox, 2016). Transitioning from automobility to

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green mobility thus not only requires embracing new technologies and ways of thinking about urban mobility, but also overcoming legacy urban forms, mobility infrastructures, behavioural habits and entrenched social inequalities.

A successful shift to sustainable mobility must address head-on the unequal social structures that already exist in cities, and also anticipate newly emerging sources of inequality that the sustainable mobility transition itself may bring about (Van Ham et al., 2021; Ballo et al., 2023). Cities attract both regional and global workforce by offering highest-paying jobs in emerging sectors (i.e. business services, information and communication technology). An economy structured around such employment sectors may grow fast, but also lead to a stratified labour market dominated by a highly-paid professional workforce (Hamnett, 2021). At the same time, each highly paid financial service or technology job creates demand for a number of additional lower-paid jobs in construction, personal-services, hotels, restaurants and related sectors (Moretti, 2013), resulting in a polarized high-low income workforce with a thin middle-class (Sassen, 2001) and high-income inequality (Van Ham et al., 2021). If low-income jobs are increasingly adopted by migrants, social and ethnic inequalities may further compound (Tammaru et al., 2016). Such labour market stratification sets the stage for mobility inequalities with strong spatial underpinnings (Tammaru et al., 2021).

Spatial theories on cities have long stressed the importance of access to daily services and amenities in home-neighbourhoods, fostering sustainable mobility at the neighbourhood scale. Early examples of home-neighbourhood based planning approaches include the Garden City concept by Ebenezer Howard (1898), the Neighbourhood Unit concept by Clarence Perry (1929), and the wide-spread adoption of the "microrayon" concept in Soviet residential town planning system (Metspalu and Hess, 2018). The "15-Minute City" concept popularized by Mayor Anne Hidalgo of Paris (Moreno et al., 2021) is the most recent iteration of such approaches that has inspired urban planners and mobility researchers alike, including in our Special Issue.

The guiding idea behind these home-neighbourhood based accessibility approaches is to promote an ample selection of daily destinations in residential neighbourhoods, within a short and safe walking distance or bike-ride, thus diminishing the need for motorized mobility. Given that trips to commercial, social, care-related and institutional destinations constitute a majority of all trips in cities (Federal Highway Administration (FHA), 2017), with work-related commutes amounting to only about a third of all trips, diverse amenity provisions at the neighbourhood scale hold real promise to change travel patterns in favour of shorter journeys near one's place of residence or work (Sevtsuk et al., 2021). However, despite the popular rhetoric of the 15-Minute City, the spatial distribution of commercial land uses follows urban economic logic, which planners and policy makers have limited influence over. Retail, food and service destination cluster in limited locations of a metropolitan area, and cultural destinations at even fewer places, making it difficult to alter unequal levels of access to such places across neighbourhoods and socio-economic strata (Sevtsuk, 2020; Hidalgo et al., 2020). Amenity clusters produce hierarchical distribution patterns, characterized by Zipf's Law, with few large regional centres, numerous mid-size agglomerations and the highest number of small, neighbourhood clusters (Sevtsuk, 2020). Only in very high urban densities, such as found in Paris, New York, London, or Hong Kong, do we find diverse amenity cluster within walking reach from most home locations. In more typical cases, the majority of residents inevitably need to travel across neighbourhoods to access daily activity destinations. Though policy makers can incentivize mixed-use developments, more housing opportunities close to existing retail clusters and new main streets outside of central business districts, specialized amenities and regional institutions can never be available in each neighbourhood—they will always be shared across an urban population. Making job centres and amenity clusters accessible via sustainable mobility across neighbourhoods—through public transit and bike and walk routes—thus offers an important direction for both decarbonizing urban transportation and addressing social equity goals. Put alternatively, cross-neighbourhood mobility connections are more important for equity than 15-min neighbourhoods within balkanized and unequal urban districts.

Additionally, levels of residential segregation have grown in large cities around the world (Van Ham et al., 2021). A shift towards active mobility centred around home-neighbourhoods in a residentially segregated city can contribute to increased spatial segregation in other important daily activity places, including workplaces, schools and leisure time facilities, leading to what Tammaru et al. (2021) call a vicious cycle of segregation. It is therefore important that planning for sustainable mobility considers wider issues of urban equity.

2. An equity-centred model of sustainable urban mobility

We propose a four-layer Equitable Sustainable Mobility model to frame the discussions around the intersection of sustainable mobility and spatial structures of urban inequality (Fig. 1). The four layers of the model are as follows: (a) distribution of the urban opportunities structured around home locations, (b) distribution of the mobility infrastructure and access to key daily activity places by different travel modes, (c) activity spaces of all family members undertaking their daily activities in urban space, and (d) share of trips taken by sustainable travel modes by different social groups.

2.1. *Opportunity distribution*

The first layer (at the bottom) of the model describes *opportunity distribution* in a city—the spatial structure of urban form, land use patterns and demographics that constitute the origins and destinations of journeys as well as the social characteristics of the travellers. Land uses, functions, institutions and activity places—their location, intensity and attractiveness throughout the built environment—constitute the elements of opportunity space that generate demand for movement and largely determine trip generation and trip distribution. These social, economic and cultural opportunities are in turn structured by the physical pattern of urban infrastructure, the two and three-dimensional geometry of built form, circulation routes, and public space laid out by the urban designer or planner to configure the change and growth of the city. Access to opportunities varies in space, depending on where one lives or works and what financial means or power in society one wields.

2.2. *Mobility infrastructure*

The second layer of the model describes *mobility infrastructure*—the availability of different modal infrastructures and travel times between spatial origins and destinations in a city. These comprise the public transit routes and schedules, the vehicular-, cycling- and walking networks of a city, as well as the spatial distribution of various shared e-mobility stations and services. Access to the mobility infrastructure is further mitigated by pricing, quality (a mixed-traffic bike-lane may feel safe to a teenager, but not to an elder), as well as physical barriers—a metro station without step-free access can be irrelevant to a wheelchair or stroller user (Swift et al., 2021). Changes in mobility infrastructure—e.g. geographic changes in service provision; shifts in pricing or fare policies and scheduling shifts—can produce spatially heterogenous and socially uneven changes to accessibility for users illustrated in the layer below. Nevertheless, the opportunity distribution and mobility infrastructure layers are most directly influenced by spatial plans, land use regulations, policies and infrastructure investments: they set the stage for or form the overall spatial structure in which the socio-economic dynamics that take place in the remaining two layers.

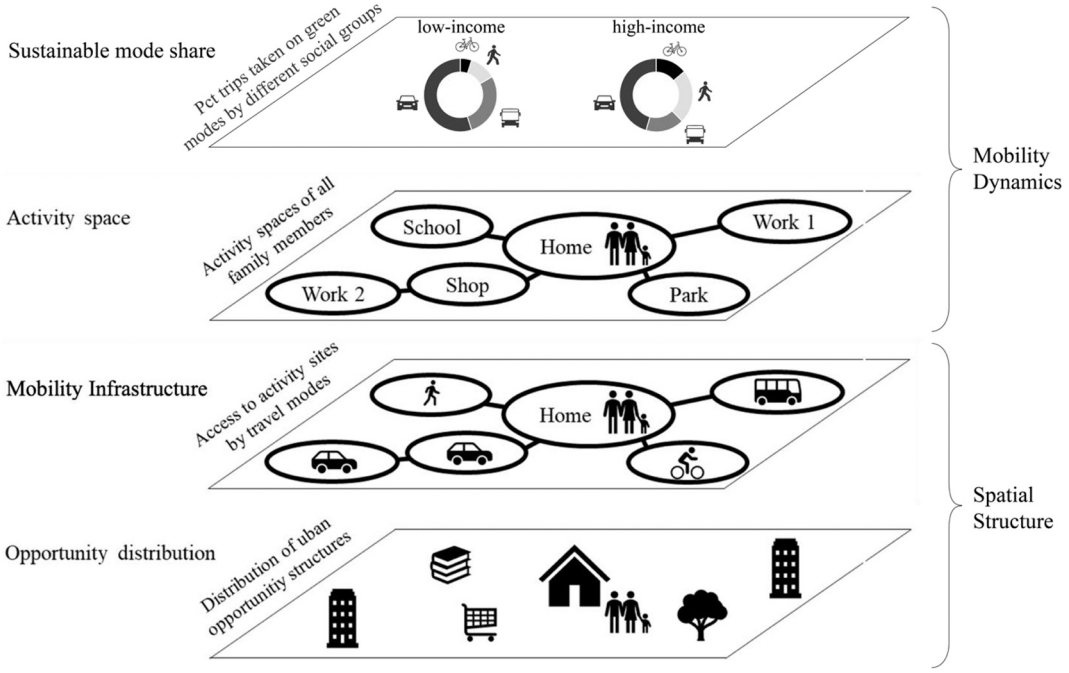

Fig. 1. The four-layers of an equitable sustainable mobility model.

2.3. Activity spaces

The third layer of the model describes *activity spaces*—chains of actual activity destinations that people visit over time (Hägerstrand, 1970; Ahas et al., 2010). This layer represents the complex and overlapping daily activity schedules and travel patterns of different social actors in a city. These patterns are never stable—they shift as households are formed, break-up or move, individuals switch jobs, amenities and institutions open or close. They also depend on changes in the mobility infrastructure, service quality and pricing. Further, even in the presence of a stable opportunity space and mobility infrastructure, people's preferences—residential location choice preferences, job location choice preferences, commercial destination preferences, and mode and route choice preferences—also change over time. The gentrification of the inner-city areas in many cities a good example of such change. The activity space layer at any point in time thus represents a temporary equilibrium of social and economic competition of space and access to opportunity in the city. While the first two layers of this framework—the opportunity distribution and mobility infrastructure—are strongly interconnected, even directed by both public and private investments and policies, the third layer—activity space—involves considerably more complex market dynamics, where a large number of actors make simultaneous destination choices, mode choices and route choices to best fit their daily needs, within their specific constraints. While residential location changes, and to a lesser extent job location changes are relatively infrequent and typically shift within years, destination choices about where to spend free time, where to run errands or meet family and friends can shift on a daily basis and depend on both daily activity schedules and person characteristics and preferences.

2.4. Sustainable mode share

Finally, the fourth layer of the model summarizes the extent to which different social groups in the city choose to reach their daily activity destinations via *sustainable mobility modes*: primarily by public transit, walking or cycling. The activity space layer, grounded in the underlying opportunity distribution of the city, largely defines the trip distribution patterns in a city, while the mobility infrastructure layer mediates the ease with which trip origins and destinations are connected by different modal options and costs. The overarching aim of an equitable and sustainable mobility transition is to facilitate the shift from polluting, energy- and space-intensive motorized mobility patterns to non-auto mobility in ways that maximize the overall mode share of greener mobility modes while minimizing an unequal distribution of benefits between different social groups. A positive outcome is thus captured by an increasing overall share of green mobility modes and decreasing deviations in adoption rates between different social groups.

2.5. Cross-level interactions

The above framework suggests that opportunities for balancing transitions to sustainable urban mobility can be primarily found on the first two levels of the mode: in affecting land use structures and mobility infrastructures. The opportunity distribution layer, suggests that residential segregation typically leads higher income groups (or other groups that hold more social power in a city) to reside closer to opportunities than lower income groups—thereby facilitating shorter, non-motorized journeys to such opportunities among the wealthy. It is thus harder to achieve an equitable shift to greener mobility, ceteris paribus, in a city of income-segregated neighbourhoods. Residential segregation can accentuate mobility inequities, resulting in systematic differences in modal options, commute times, and accessibility levels to jobs, amenities, leisure destinations, and other opportunities. Countering residential segregation is complex and necessitates multi-sectoral policy approaches, but concrete actions such as an extensive provision of public or not-for-profit housing throughout all city districts (e.g. in Singapore and Vienna) and the imposition of income-limits and housing affordability brackets in transit-oriented residential developments (e.g. in Berlin and Paris) have offered promising solutions in some contexts. Similarly, numerous post-Soviet cities in Eastern Europe maintain large amounts of pre-fabricated multi-story apartment stock that has de facto served as affordable housing in rather central sites (Hess and Tammaru, 2019). Renovating and modernizing that housing stock offers a pathway to less segregated housing patterns and thus lower inequality in the sustainable mobility transition. These tactics represent policy interventions in the *opportunity distribution* layer.

An equitable transition to greener mobility outcomes can also be achieved with targeted interventions in *mobility infrastructure* layer. A

number of cities have introduced policies that require new e-mobility services, such as shared bicycles and e-scooters to be made available across variable socio-economic neighbourhoods (Ballo et al., 2023). These efforts stand in addition to public sector initiatives to ensure reliable and affordable public transportation in neighbourhoods that need it the most (Cervero, 1998). For instance, the City of Boston recently established its first fare-free bus line along Blue Hill Avenue, connecting one of the most historically marginalized neighbourhoods of the city with downtown jobs and opportunities. A number of papers in this issue discuss additional interventions, where an equitable transition to greener access is led by targeted interventions in *mobility infrastructure* (maximizing the overall share of sustainable trips, while minimizing inter-class differences in access between neighbourhoods. The layers in Fig. 1 allow us to frame the aims of an equitable sustainable mobility transition simultaneously in terms of an overall increase in non-carbon intensive trips as well as an equitable access of non-auto travel to different social groups.

The four domains of an equitable sustainable mobility model—opportunity distribution, mobility infrastructure, activity spaces and the inter-group sustainable mode share outcomes—are closely intertwined with each other. Deliberate policy and planning approaches to counter market-led inequalities in the sustainable mobility transitions require purposeful market corrections, such as progressive fare policies that make new mobility services accessible across income levels, distributing new mobility infrastructure to less affluent neighbourhoods, and housing policies that address the high levels of residential segregation. However, residential segregation remains a longstanding challenge that cities must confront (Nightingale, 2012). Understanding the uneven distributions of ethnic and socioeconomic groups across urban neighbourhoods and how this relates to their activity patterns and opportunities to switch to greener travel modes is thus the first element in our equity-centred model of sustainable mobility.

3. Home locations, urban opportunity structures and the vicious cycle of segregation

An Equity-centred Model of Sustainable Mobility (Fig. 1) considers residential neighbourhoods as the most important spatial anchor points for daily mobility since home locations are the most common start and end points for daily trips, shared among household and family members (Ahas et al., 2010; Candipan et al., 2021). People sort into neighbourhoods based on their needs to get access to various urban opportunities such as schools, workplaces and leisure time activity sites, and the neighbourhood of residence in turn shapes access to these urban opportunities. Home locations and access to opportunities are highly interdependent. The concept of a vicious cycle of segregation provides a framework for understanding this interdependency (Tammaru et al., 2021). Its starting point is based on individual social and spatial mobility, and on the mechanisms that sort individuals with different characteristics (income, ethnicity, etc.) into unequal social and spatial positions (cf. Schnell and Yoav, 2001).

The intensity of sorting into different neighbourhoods depends on several factors such as the overall proportion of households with higher and lower incomes (Sassen, 2001) and the level of income inequality between them (Tammaru et al., 2020). Sorting of different ethnic and income groups into specific neighbourhoods also depends on the spatial characteristics of local housing markets and on the residential location-choice preferences of different income groups. In a city, where most neighbourhoods provide diverse housing options, including below market-rate public housing, residential segregation is slower to rise. In a city of segregated housing typologies, residential segregation is more rapid to rise. Money buys choice on the housing market (Hulchanski, 2010) and, hence, the residential preferences of the higher-income households combined with the spatial patterns of housing stock jointly determine the spatial landscape of urban equity (Haandrikman et al., 2021). A recent comparative study by Van Ham et al. (2021) reveals inner-city gentrification of higher-income households in major cities around the world. Proximity to waterfronts and urban amenities in inner cities lures wealthier white-collar office workers with attractive residential environs (Fig. 2). The concentration of higher-income households goes hand-in-hand business services that cater to their needs (Wessel, 2022). Concentrated wealth in city centres (and waterfronts, if available), contributes to a concentration of amenities as showcased by cities like Dubai, London or Singapore.

High housing costs in inner cities push lower-income households to those parts of the suburbs that offer more affordable housing options (Van Ham et al., 2021). In many cities that witnessed a flight of the middle and the upper-middle classes from inner city neighbourships during post-war decades due to motorization and supporting housing policies, residing in central urban areas helped less affluent households gain access to important daily services and activity places. The current demographic inversion and inner-city gentrification (Ehrenhalt, 2012; Hartley et al., 2016) reverses these patterns and poses important mobility challenges for lower income renters that are being pushed out to more affordable housing areas in the suburbs (Delmelle et al., 2021). However, a lack of transit services in low-density districts requires disproportional expenditure on private transportation to access jobs. Furthermore, a co-location of lower-income jobs and households in peripheral sites may contribute to inter-generational transmission of urban inequalities as schools often draw children from nearby residential areas (Kalm et al., 2023). The more homogenous these catchment areas, the less opportunity for inter-class encounter and mixing exist also for children. Changes in residential segregation thus tend to evolve together with changes in the geography of workplaces, schools as well as leisure amenities, producing a growing overlap between residential segregation and workplace segregation (Delmelle et al., 2021), residential segregation and school segregation (Bernelius et al., 2021) and residential segregation and leisure time segregation (Kukk et al., 2019).

Whether and how urban land use patterns and spatial segregation impact an equitable adoption of sustainable urban mobility, further depends on the spatial structure of cities. The role that urban form can play in mitigating the segregation-mobility nexus has so far remained less explored in research. For instance, European cities tend to have denser and more mixed-use historic structures, making walkability and public transit access viable for a larger population share. American metropoles tend to be less dense, featuring large regions of single-family housing, where the private automobile remains the overwhelmingly preferred modal option for travel. It is unsurprising that the 15-Minute City concept recently emerged in Paris, where it has already been a reality with over to 85% of modal share sustainable (C40 Cities Climate Leadership Group, 2020).

Similar to Paris, in cities where denser urban growth has been planned near transit connections for decades—Copenhagen, Stockholm, Singapore or London, to name a few—existing urban form already supports more equitable access to sustainable mobility options (Cervero, 1998). But in much of the urban world, the preconditions for a broad-based sustainable urban mobility shift are less favourable. In numerous North American cities, walkable and transit-oriented neighbourhoods are rare and market competition for such location can be steep, making living or working in walkable neighbourhoods a relative luxury (Lynch and Leinberger, 2014). In the Global South, urban districts with relatively high sustainable mobility outcomes (i.e. informal settlements) may be widespread, but their sustainable mobility benefits must be weighed against adverse sanitation, public health and quality of life challenges (Shaban and Aboli, 2021). Furthermore, institutional challenges around land-use and transportation coordination have made Transit-Oriented Development and Pedestrian-Oriented Design challenging in countless rapidly-growing cities in South-East Asia, South-Asia, the Middle East, South America, and Africa. Several East Asian countries, on the other hand—Japan, Korea, China, Taiwan, Singapore and more recently, Thailand, Indonesia, Malaysia among others—have made significant public investments into mass transit systems in large

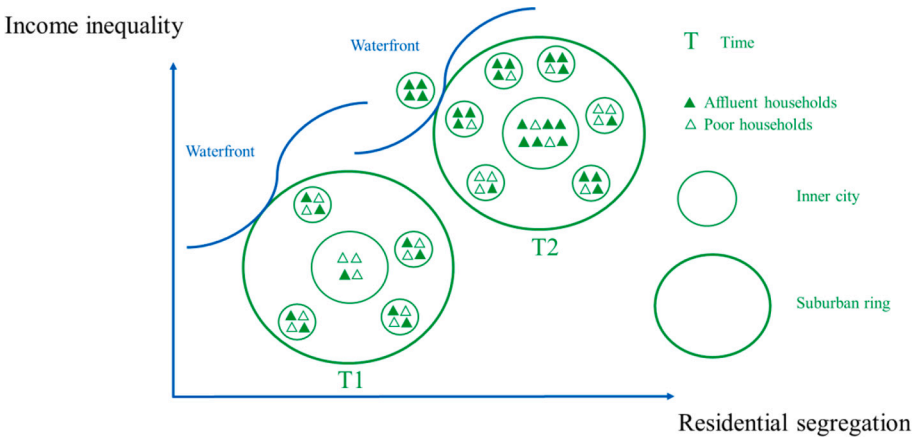

Fig. 2. Changes in urban income inequality and residential segregation with time.

metropolitan areas, offering high quality cross-neighbourhood connections without resorting to cars. Developing a better understanding of how urban form and emerging transportation infrastructure patterns can mitigate transitions towards greener mobility therefore presents another key focus area in this Special Issue.

To summarize, residential sorting of households with different incomes are closely related to other socioeconomic and geographic processes in the city, giving rise to vicious cycles of segregation (Tammaru et al., 2021). Home-neighbourhood focused urban interventions thus risk contributing to the transmission of residential segregation to the full spectrum of activity spaces beyond home locations. In order to avoid further segregation, home-focused non-auto accessibility improvements would benefit from a better understanding of how urban inequalities and segregation are produced and reproduced in cities with different urban forms and land-use patterns.

4. A shift to greener mobility: uncovering the spatial underpinnings of urban inequality

An Equity-centred Model of Sustainable Mobility (Fig. 1) aligns with the growing understanding that mobility solutions should not only be efficient and sustainable, but also equitable, balancing the needs of different population groups (Di Ciommo and Shiftan, 2017; De Paepe et al., 2023). Inequalities tend to accumulate—high levels of spatial segregation tend to be correlated with high levels of mobility inequality (Levy et al., 2020; Candipan et al., 2021). Spatial segregation of residents in car-dominated cities can lead to unequal access to workplaces, schools, and amenities for low-income households, ethnic minorities, women, the elderly, and people with disabilities (Anciaes and Jones, 2020; Liu et al., 2023; Lucas, 2012). Low-income households are least likely to own a car and therefore most mobility-constrained in car-oriented cities, especially when it comes to long-distance trips from peripheral locations (Lucas, 2019). Would the application of the 15-Minute City concept and a policy shift towards greener mobility benefit groups that were already disadvantaged in a car-oriented city? In elaborating the sustainable mobility paradigm, Banister (2008) argues that while the conventional approach in transport planning has facilitated segregation of people and traffic, the shift towards sustainable mobility would facilitate an integration of people and traffic. Lucas (2019) diversifies the discussion by highlighting that there are diverging views when it comes to the relationship between inequality and green mobility:

> On the one side are the optimists, who believe that the new landscape of autonomous vehicles, robotic deliveries, shared mobility and mobility as a service (MaaS) will allow people who are currently not able to own or drive their own vehicles to have new access to the benefits they derive. On the other side are the pessimists, who predict an increased concentration of transport wealth among the already privileged and partial or a total lock-out of the people and places who cannot access these services for reasons of their unaffordability or non-operability within certain spatial contexts, e.g. sparsely populated and remote areas … If more people are located in suburban areas, the demand for travel will be more dispersed and less easy to cater for through mass transit solutions, suggesting that transport services will be more fragmented.

Ride-hailing, car-sharing and bike-sharing services, for example, have witnessed a steady growth in demand in the last decade, lowering the cost of mobility compared to personal car-ownership (Storme et al., 2021). However, shared mobility solutions are not equally accessible in all urban neighbourhoods and for all social groups, particularly those located in less dense suburban fringes. Likewise, the travel needs of some social (vulnerable) groups are less suited to shared travel—the elderly, women, or travellers who consistently require more complex chained-trips due to care and family needs (Lucas, 2019; de Madariaga and Zucchini, 2019). Also argue that technological innovations tend to reinforce rather than mitigate existing mobility inequalities unless equity concerns related to safety, affordability or infrastructure distribution for walking and biking are explicitly addressed in the planning process. New forms of inequality stemming from a policy push in the name of sustainable mobility may compound existing inequalities. For example, access to public transit varies significantly during day and night (Smeds et al., 2020). While high-income and white-collar office work is centred around regular working hours when public transit works, low-income manual worker work hours are more likely to fall outside of regular transit schedules, taking place over night or starting early in the morning, before transit services commence. Transit inequality may also take a more nuanced form, such as service reliability and differences in waiting times between urban neighbourhoods. Javanmard et al. (2023) Javanmard et al. (2023) find that delays and pass-ups are more common in minority neighbourhoods compared to non-minority neighbourhoods based on a study in Winnipeg, Canada. Plans and policies for greener mobility may thus provide opportunities for people who were disadvantaged in a car-oriented city, or instead contribute to inequality by accentuating benefits for the already privileged residents while reinforcing existing inequalities. New public transit investments and street-based infrastructure improvements for facilitating active mobility are often concentrated in inner-city environments, where highest residential and employment densities are found, but investments in such areas also compound inequality (Wågsæther et al., 2022).

A market-led shift from auto-oriented mobility towards greener mobility can therefore lead to elitist sustainable mobility, benefitting high-income households in the inner-cities the most (Fig. 3). Trips in city

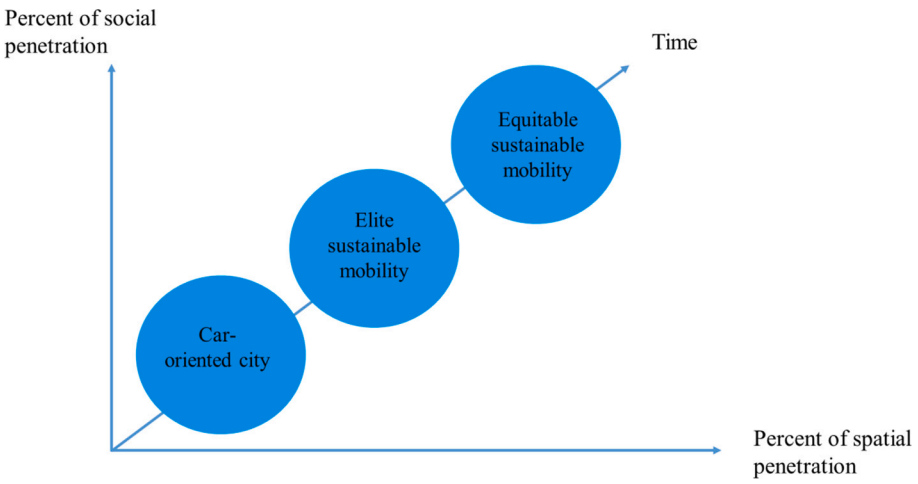

Fig. 3. Changes in the social and spatial penetration in a shift to sustainable mobility.

centres tend to be significantly shorter than in suburbs (Toger et al., 2023), allowing for an easier shift to green alternative modes (Poorthuis and Zook, 2023). At the same time, better access to the emerging mobility services fosters stronger and earlier adoption by higher-income individuals (Mohiuddin et al., 2023). Reducing car access in city centres, and making public investments into transit, e-mobility and active mobility tend to bolster property values, further enforcing the inequality gap (Wågsæther et al., 2022), forcing the less affluent households to seek alternatives in suburbs and peri-urban areas (Hochstenbach and Musterd, 2018). Households residing in suburban and peripheral areas tend to have lower access to emerging sustainable mobility infrastructure, facing fewer opportunities to benefit from transport-related real-estate appreciation and fewer alternatives to cars in driving to work and to other daily destinations.

Socio-economic gaps in the sustainable mobility transition are further evidenced by the fact that early adopters of sustainable mobility solutions, such as cycling, car-sharing, or electric vehicles tend to be "choice" riders. These early adopters have the financial means and abilities to choose between alternative travel modes, while lower-income households lack the resources to experiment modal choices. As a result, even if "car-lite" mobility investments are implemented in less privileged neighbourhoods, their very presence can trigger gentrification and a demographic shift, whereby wealthier households can move in to benefit from improved multi-modal access, but without abandoning their higher car-ownership rates (Basu and Ferreira, 2020, 2021).

5. Key takeaway messages of the special issue

Achieving a shift from carbon-fuelled automobility to sustainable mobility in cities is crucial to limiting greenhouse gas emissions and slowing global warming. However, policies aimed at reducing greenhouse gases by promoting active forms of mobility and by shortening daily trip distances often clash with urban equity aims. The papers collected into this special issue discuss the strategies and tactics for achieving a faster, more efficient and more equitable adoption of green urban mobility. Contextualized within the wider research findings in the field, the papers yield three key messages for an Equity-centred Model of Sustainable Mobility.

Address high levels of residential segregation to facilitate neighbourhood-level housing mix.

An excessive emphasis on local-area accessibility (e.g. the 15-Minute City concept) in the presence of high levels of residential segregation could thus transmit patterns of the residential segregation into other important daily activity places such as schools, workplaces and leisure time venues, thus further accentuating urban inequalities. Mechanisms behind residential segregation may be very different in different urban contexts given city size, urban form (compact or sprawled), welfare regimes and institutional context. The study by Shen and Luo (2023) draws its empirical evidence from Shanghai. Focussing on the hukou ("household registration") status as the key dimension in urban inequality in China, they employ an individual-level spatiotemporal proximity approach to measure multi-contextual segregation. The findings show that migrant and rural populations experience higher levels of segregation, not only in residential neighbourhood, but also in other daily activity places. The study by Nilsson and Delmelle (2023) is based on Charlotte,North Carolina metropolitan area. Their research shows that higher-end housing and active mobility opportunities are often jointly advertised, attracting higher income people to inner city neighbourhoods, while the advertisements of suburban neighbourhoods feature more often automobility related benefits, and attract lower-income and minority households. Tominga et al., 2023 focus on the daily travels of people living in two segregated neighbourhoods in the Estonian capital city Tallinn, one in the inner city and the other in the suburb. By undertaking a mobile phone tracking experiment, they find that walking (also in combination with other travel modes) is more common in the more affluent city centre, while car use is more common in the suburban neighbourhood. Poorthuis and Zook (2023) study in the Netherlands argues that a key pathway to more equitable green mobility is to offer affordable housing in dense city centre districts that are already equipped with access to green mobility options.

5.1. Radical shift of urban space is needed from automobility to different forms of green mobility

Existing research shows that car ownership has declined in many European cities, a phenomenon that has been termed car saturation (Goodwin and Van Dender, 2013), and this decline applies to all income groups and could be mostly seen as a generational shift that relates to younger travellers (Grimal et al., 2013). In order to facilitate a faster shift from carbon-intensive automobility to sustainable mobility could be achieved by focusing on constraints to this this shift, including capability constraints, coupling constraints and authority constraints. Ballo et al. (2023) turn their attention to the new and promising solutions for city-wide connectivity provided by e-bikes, proposing the concept of *E*-Bike City, joining with the calls to redistribute about half of road space from cars to alternative travel modes. They advocate electrically-assisted bikes as a more inclusive, potentially contributing to the wider adoption of sustainable travel modes among more diverse population groups, including the elderly and the disabled. E-bikes allow also an easier access over the longer distances, as well as higher individual flexibility and lower cost than traditional transit. While many cities have already created exclusive lanes for public transit, much more

can be done in investing into high-quality, city-wide cycling infrastructure that considers also different travel speeds. Mohiuddin et al. (2023) use data from a two-wave survey of e-bikeshare users and a household survey of residents in the Sacramento region. They find that that lower-income people are less likely to adopt bike-share but they use the service more frequently than other income groups when they do adopt. Individuals living in Sacramento and West Sacramento are significantly more likely to adopt and use bike-share than suburban residents in living Davis. However, Davis enjoys higher density of bike lanes. Other interesting findings surfaces as people living in Davis are more likely to use e-bike-sharing for commuting to work that may refer to the effectiveness of e-bikes in catering the demand for longer trips.

5.2. *Both close-to-home and metropolitan area-wide solutions in access to opportunities are needed*

Urban planners are inspired by the 15-Minute City concept that calls for shorter trips by sustainable travel modes. However, neither jobs nor other urban opportunities can be equally distributed across all neighbourhoods (Sevtsuk, 2020). Providing sustainable and affordable inter-neighbourhood connections to jobs centres, business districts, cultural clusters and civic institutions located also further away from homes is therefore a key element for a more equitable transition to green mobility. Combining public transit and walking remains the most efficient way in providing connections to opportunities sustainably and equitably over the longer distances. The study by Shao et al. (2023) shows that both raising the density of the public transit stations as well as incorporating Internet-based information services into transit systems will be an effective strategy to encourage transit ridership and contribute to use of sustainable travel modes in travelling over longer distances. However, the study conducted by Wang and Yang (2023) highlights a significant challenge associated with the use of public transit, indicating a correlation between transit use and mental health concerns among women, but not among men. As a switch from cars to public transit is especially important for people living in suburbs, policies that encourage higher transit ridership should be more gender-aware, paying attention to issues such as security (including robbery and harassment), crowdedness and long waiting times that are often observed in public transport and that may worry women more than men.

Ryan et al. (2023) focus on differences in the distribution of accessibility to the workplace by public transport combined with walking during multiple departure time periods. Based on travel survey data for the Stockholm region, their research shows that the flexibility to travel during different timeframes and to work from home tends to be concentrated in higher-income groups, living in the wealthier parts of cities. Toger et al. (2023) trace the mobility patterns of people living in greater Stockholm area using individual pseudonymised mobile phone data. They find that people living in suburbs have to undertake longer trips to access urban opportunities. Willberg and Fink (2023) broaden the equity perspective by arguing that many popular concepts such as 15-Minute City take the perspective of an average person on an average day in addressing accessibility to key activity places, while actual life is more diverse. Studying population groups with different walking characteristics in Helsinki Metropolitan Area, they find considerable age-based and seasonal differences in access to opportunities, concluding that it is important to pay more attention to the needs of vulnerable population groups. The study by Liu et al. (2023) takes a more specific interest to the access to public transit by people with disabilities. Based on high resolution public transit real-time vehicle data from Columbus metropolitan area, Ohio, they find large disparities in wheelchair users' accessibility relative to people without disabilities.

The key equity concern running through the papers in this issue points to spatial inequalities, particularly differences between city centres and suburbs. Various interventions aimed at facilitating sustainable mobility, such as reducing car access to city centres or redistributing street space from automobiles to more sustainable travel modes, run the risk of further increasing the spatial advantages of city centres over their hinterlands, which must be balanced with equalizing inter-district transit investments and affordable housing implementations at more central sites. Future research should focus more explicitly on the unintended equity consequences of the green mobility transition. The proposed Equitable Sustainable Mobility model could serve as a good starting point for framing such research.

Data availability

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