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Fair street space allocation: Ethical principles and empirical insights

Felix Creutzig[a,b], Aneeque Javaid[b], Zakia Soomauroo[a,c], Steffen Lohrey[a], Nikola Milojevic-Dupont[a,b], Anjali Ramakrishnan[a,b], Mahendra Sethi[a,b], Lijing Liu[a], Leila Niamir[b], Christopher Bren d'Amour[a,b], Ulf Weddige[b], Dominic Lenzi[b], Martin Kowarsch[b], Luisa Arndt[a], Lulzim Baumann[a], Jody Betzien[a], Lesly Fonkwa[a], Bettina Huber[a], Ernesto Mendez[a], Alexandra Misiou[a], Cameron Pearce[a], Paula Radman[a], Paul Skaloud[a] and J. Marco Zausch[a]

[a]Sustainability Economics of Human Settlements, Technical University Berlin, Berlin, Germany;
[b]MercatorResearch Institute on Global Commons and Climate Change, Berlin, Germany;
[c]Reiner Lemoine Institute,Berlin, Germany

Abstract. Urban street space is increasingly contested. However, it is unclear what a fair street space allocation would look like. We develop a framework of ten ethical principles and three normative perspectives on street space – *streets for transport*, *streets for sustainability*, and *streets as place* - and discuss 14 derived street space allocation mechanisms. We contrast these ethically grounded allocation mechanisms with real-world allocation in 18 streets in Berlin. We find that car users, on average, had 3.5 times more space available than non-car users. While some allocation mechanisms are more plausible than others, none is without normative implications. Without exception, all principles suggest that on-street parking for cars is difficult to justify, and that more space should be allocated to cycling. We argue that street space fairness principles should be systematically integrated into urban and transport planning.

1. Introduction

Street spaces shape public life in the city. Streets are multifunctional, used by all, and these uses have been contested throughout urban history. Following the advent of individual motorized vehicles early in the 20th century, transport engineers allocated street space for a singular function: the movement of motorized vehicles, subordinating other uses. The corresponding shift in street space allocation and design has had profound social, environmental and economic impacts, many of which are not immediately apparent (Appendix A). Another transition is now underway driven by a number of factors including, increasing congestion and conflicts over space in inner cities, the rapid ascent of new mobility services, and climate change and sustainability ethics questioning GHG emissions and resource use. In this context, fair street space allocation is a key challenge. Moreover, questions of fairness are salient to users of urban transport systems. Despite this, the question of fair street space allocation is surprisingly little explored in the literature and academic discussions.

Street allocation differs from city to city, from district to district, and from street to street. Cities diverge in their transport patterns and can be sorted into different types, including walking cities, transit cities or auto cities (Barter, 1999). While some cities actively strive for low-carbon transport systems (e.g. Copenhagen, Medellin, or Freiburg (Buehler & Pucher, 2011; Colville-Andersen, 2018; Creutzig et al., 2012; Fernandez Milan & Creutzig, 2017)), the predominant model of urban development is still oriented towards the car. Traffic engineers still optimize the allocation of road space towards maximizing traffic flow, and justify such framing with cost-benefit analysis (Currie et al., 2007; Zheng & Geroliminis, 2013). This in turn codifies a (hidden) political choice prioritizing car mobility over cycling, walking and public transit (Hartman & Prytherch, 2015; Nello-Deakin, 2019). But cities that discourage human-scale mobility drive social exclusion by penalizing residents without a car (Boyce, 2010). In fact, urban streetscape design translates into access and equity in the city, and is an indicator for quality of life (Dover & Massengale, 2013). At the local level, communities are increasingly reclaiming the street as a public space. For instance, spearheaded by Jan Gehl and others, Copenhagen street space is a model for human-scale mobility (Gehl, 2013). Other solutions are spreading globally. Inspired by Ciclovia, a weekly event in Bogota, Colombia, there is now a Raahgiri Day every Sunday in Gurgaon and Delhi, India, during which stretches of road are blocked to motorized vehicles and opened to the public. The overall urban mobility narrative also appears to be changing. Emerging concerns about transport emissions, global warming, public health and urban sustainability have reinvigorated public discussion about the function and fairness of street space allocation. In this context, it has become increasingly important to systematically study ethical principles of street space allocation.

In this paper, we investigate the fairness principles of street allocation. We first outline ten ethical principles, three normative perspectives on the purpose of street space, and develop 14 allocation mechanisms (AM) that we map in relation to the ethical principles. We then compare the fairness principles with current street space allocation, using Berlin as our case study. We uncover a systematic bias in current street space allocation towards private cars, especially space allocation for car parking, which cannot be justified by any of the underlying ethical principles or normative perspectives. We thus call for a reconsideration of street space planning paradigms, designing new ones, that respect ongoing urbanization, the local desire for livable places, and the planetary crisis, and that build on widely accepted ethical principles.

2. Methods

Our methods comprise a theoretical conceptualization, rooted in ethical theories and normative perspectives, and an empirical analysis (see Figure 1).

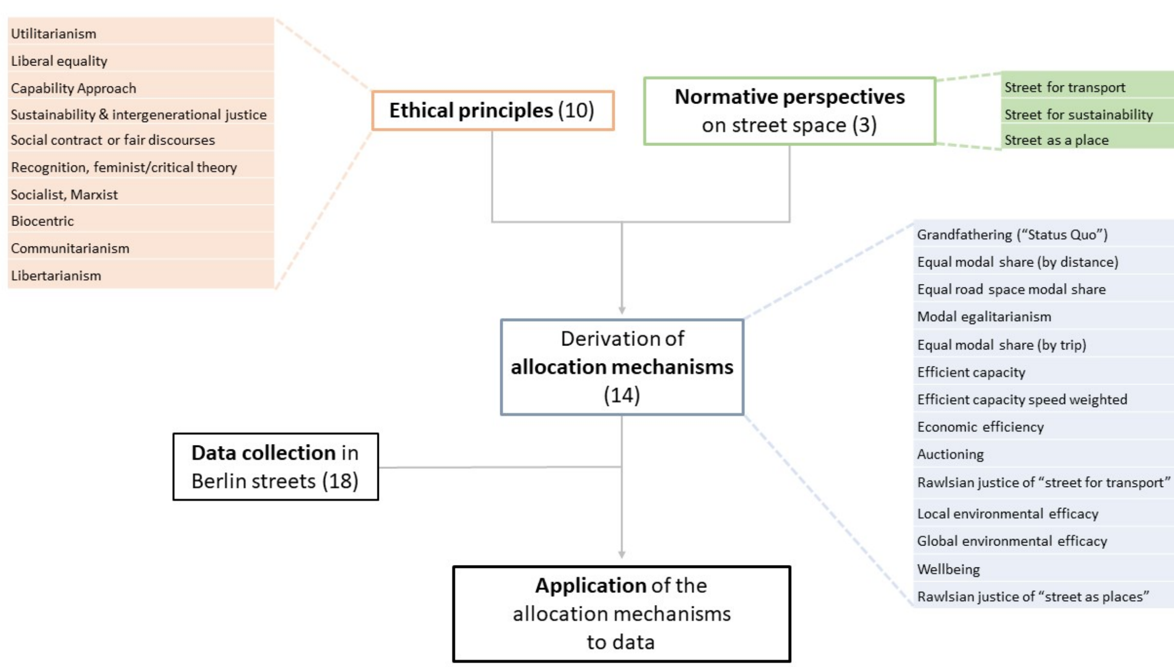


Figure 1 | Methodological Flow of the paper. Ethical principles (10) and Normative perspectives on streetscapes (3) are merged in a framework to derive 14 Allocation Mechanisms and corresponding metrices to assess them. Data collected from a primary survey of Berlin streets and secondary data is applied to quantify and analyze the metrices.

The ethical analysis has two components. We establish our base ethical framework using ten ethical principles (see 2.1) and complement it with three more specific normative perspectives on streetscapes (see 2.2). We devise fourteen allocation mechanisms that in our interpretation reflect both the ethical principles and normative perspectives. As recommendations on desirable street allocation do not solely depend on ethical principles but also upon cities' infrastructure, we propose metrics to quantify current street space.

In our case study of Berlin, we quantitatively assess street allocation at the city-level and use in-depth street-level examples. At the city-level, data for the empirical analysis is gathered from existing literature. This data offers representative statistics of street space allocation. At the street level, additional data was collected in 18 streets of Berlin in order to provide a concrete impression of how allocations materialize in actual human-experienced environments. We then retrieved street level information about space allocation and number of users of each transportation mode.

2.1. Ethical principles

Our analysis builds on standard ethical principles taken from past and contemporary debates in practical philosophy (Bird, 2019; Kymlicka, 2002; Wolff, 2015). For simplicity, we only focus on the most essential characteristics of the ethical principles and apply them to the basic street space issue (Table 1). We divide these ethical principles across three dimensions: (1) what they regard as key ethical values (e.g. liberties, happiness or well-being or capabilities, fair procedures, or community values); (2) who should be taken into account as moral objects (e.g. contemporary populations only - worldwide or only within a particular community -, or also future generations, or all living beings, as claimed by biocentrism); and (3) the principle/s of distribution used to allocate goods (e.g. equality, overall aggregate wellbeing, sufficiency, or priority for the worst-off). While this does not offer a comprehensive account of the ethical principles, covering the "key distinguishing features" of each of these principles here provides us with the opportunity to open up the debate about street justice towards, making alternative normative viewpoints explicit.

Table 1. Ten Ethical principles, their proponents, and how they relate to street space issues.

Ethical principle	Key Proponents	Core ethical aspects of street space issue
Utilitarianism	Jeremy Bentham John Stuart Mill Peter Singer	How can street space allocation serve the goal of maximizing aggregate happiness?
Liberal equality	John Rawls	How does a fair street space allocation ensure equal basic liberties, and benefit the least well-off?
Capability Approach	Amartya Sen Martha Nussbaum	How does the street space set-up enable or restrict the availability of valuable choices, capabilities, and functionings?
Sustainability & intergenerational justice	Brian Barry Eric Neumayer Derek Parfit	How does urban allocation affect the choices open to future generations, and the functioning of natural systems?
Fair discourses	Jürgen Habermas	To what extent is street space allocation decided by procedures grounded in the equal moral status of persons?
Recognition, feminist/critical theory	Gerda R. Wekerle Clare Cooper Marcus Anita Sarkissian	How does street space allocation redress pre-existing power, gender, wealth, and social status inequalities?
Socialist, Marxist	Karl Marx Friedrich Engels Robert Owen	How does street space allocation help to redress class imbalances and inequalities?
Environmental values, including biocentric views	Albert Schweitzer Paul W. Taylor Aldo Leopold	How does human use of street space influence non-human living beings and ecosystems?
Communitarianism	John Goodwyn Barmby Michael Walzer Michael Sandel	How does street allocation affect community life and cultural values?

Libertarianism	Robert Nozick James M Buchanan Friedrich A. von Hayek	How does street allocation affect the liberty of individuals?

2.2. Normative perspectives and allocation mechanisms

To normatively evaluate the allocation of street space, we also specify three prevalent normative perspectives, which imply several of the more fundamental ethical principles: 1) a transport-only perspective (*streets for transport*), 2) a climate and sustainability perspective (*streets for sustainability*), and 3) a wellbeing perspective (*streets as a place*). They serve as organizational principles that guide street allocation. These perspectives are elaborated through core components that link the effects of urban transportation and street space allocation with the corresponding perspective (see appendix for detailed discussion). *Streets for transport* includes narrow economic/transport engineering utilitarian considerations, whereas broad morally utilitarian perspectives are reflected in *streets as a place*. Rawlsian deliberations enter both *streets for transport* (the difference principle within all transport users) and *street as a place* (the difference principle within all users of streets, even if not for mobility purposes). For details on the normative perspective see Appendix B.

For each perspective, we formulated several plausible operational definitions that we call ‘allocation mechanisms’ (AMs) - guidance metrics for evaluating fairness of space distribution. AMs specify the normative perspectives, which are in turn motivated by one or more specific ethical principles. Nonetheless, given the inherent vagueness and interpretability of ethical principles, we do not claim that other interpretations are impossible. Our interpretations are merely one plausible way to interpret them. Fig. 2 presents the three organizational principles, their specifications as street space allocation mechanisms (AMs) and their connection with the different ethical principles.

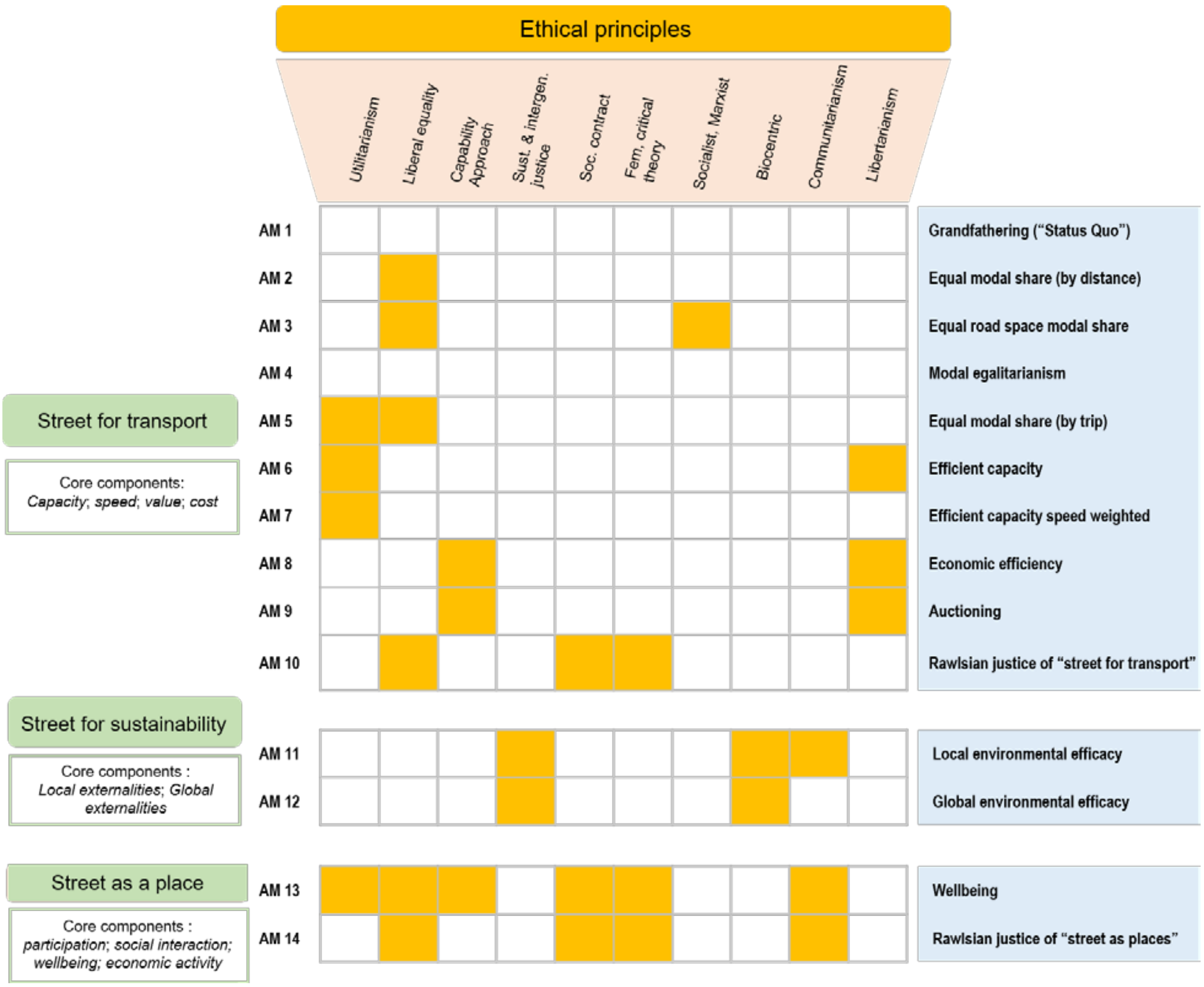


Figure 2. Allocation Mechanisms and ethical principles. The grid maps the 14 allocation mechanisms across the ethical principles and normative perspectives. The mechanisms are grouped based on the respective normative perspectives.

AM 1 (Grandfathering) represents the status quo and as such is not based on any explicitly considered normative perspective. Rather it reflects the current situation and serves as a baseline for comparison to other scenarios. The majority of the proposed allocation mechanisms (AMs) address the purpose of streets for transport. AMs 2-5 explicitly consider modal share, and are drawn bottom-up from a transport engineering view. They are partially motivated by transport-utility concerns. AM 2 takes modal share by travel distance as the relevant core element, whereas AM 3 and AM 5 consider road space and modal share by trip number as the relevant metrics respectively, thus giving similar value to each road user. The ethical principle of liberal equality, but also interpretations of utilitarianism and socialism underpin thus street space allocation. AM

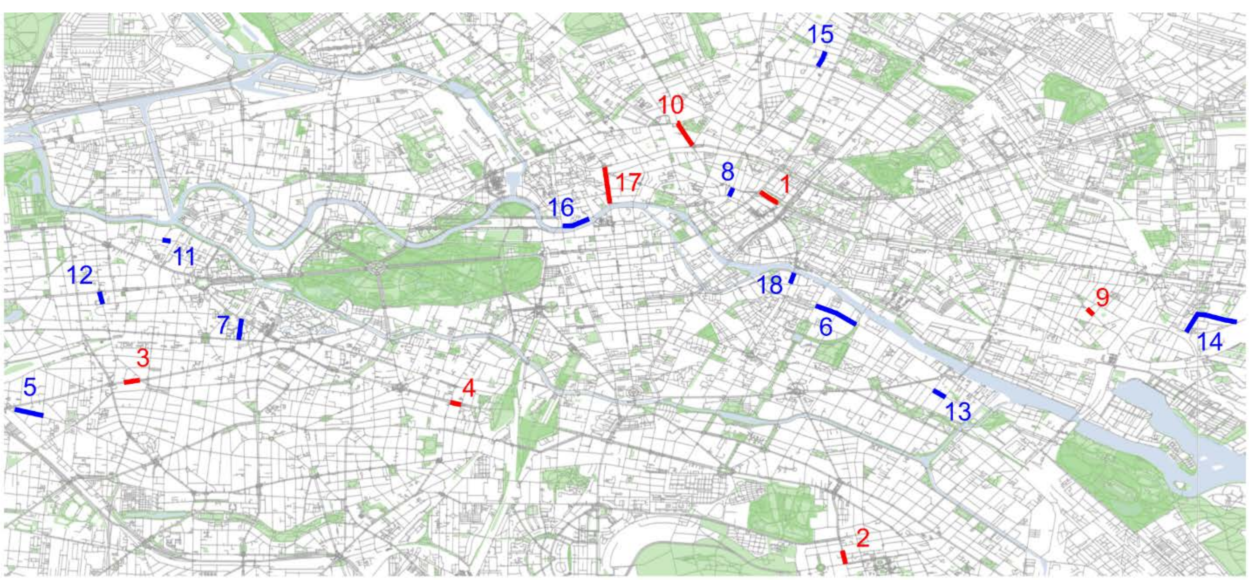
4 strives for functional clarity by providing equal space to all modes, and serves as an example that can hardly be justified by any ethical principle. AM 6-8 base allocation on efficiency of the mode in terms of carrying capacity or economic value (trip/km), reflecting both utilitarian and capability-based ethics. AM 9 and 10 address the use of the street for transport by allocating space to those who pay most for the change, reflecting the libertarian priority given to individual autonomy, regarding the status quo distribution as presumptively justified. AM 10 explicitly adopts the difference principle of Rawls, and allocates streets to improve mobility of those who are least advantaged.

Streets for *s*ustainability is addressed by AMs 11 and 12 that lay out normative considerations for environmental efficacy. At the same time, owing to different scales of their efficacy (11 – local and 12 – global), they prove useful in meeting transport needs when specified together, and not separately. Local environmental efficacy (AM 11) aims to minimize local air pollution while Global environmental efficacy (AM 12) would aim to minimize the implications for climate change and resource use. The two AMs satisfy principles of sustainability & intergenerational justice and that of environmental values, including those of biocentrism, ecocentrism, environmental pragmatism, and enlightened anthropocentrism. AM 13 addresses the purpose of *streets* as a *p*lace, emphasizing human needs, capabilities, and wellbeing for all, but also reflecting communitarianism. AM 14. AM14 combines the previous view with that of Rawls, giving additional emphasis to those least advantaged, such as children and the elderly.

3. Comparing principles with empirical observations: A Berlin case study

Berlin's explosive expansion at the turn of the 20th century was fueled by the then new technology of rail-based mass-transit such as tramways. Post-war reconstruction efforts, in contrast, aimed at a transformation towards a car-friendly city, erasing previous urban structures for highway construction in both the East and the West. In the decades after World War II, all strategies were focused on motorized transport (Thomson, 1978). Despite a history of automobility promotion, resulting in nearly 60% of street space allocated to cars, in contemporary Berlin only 17% of all trips are made by car (Agentur für clevere Städte, 2014). The city has a very low-rate of motorization by global standards - 342 cars per 1,000 inhabitants, and 0.47 cars per household inside the "S-Bahn Ring" (Jahn & Krey, 2014). A representative study found that 39% of Berlin's public-street area is dedicated to driving cars and 19% to parking them, meaning that more than half (58%) of the city's public street space is consumed by the least space-efficient mode of transport, the automobile. 33% of street space remains for pedestrians, and only 3% is dedicated cycling infrastructure (Agentur für clevere Städte, 2014). In addition, there are 130,000 off-street parking spaces, 50,000 attached to supermarkets or discounters, and 80,000 in parking garages (Reidl, 2019). Yet, even though street space is car centered, cars are not the dominant mode of transport. In the inner city, where the survey presented in this paper was conducted, 35% of trips are made by walking, 29% by public transportation, 18% by cycling and only 17% by car (Ließke, 2013). The total Berlin modal share of trips, including in the suburbs, breaks down to 26% by walking, 27% by public transit, 15% by cycling, and 34% by cars (Nobis, 2019). This clearly demonstrates the necessity to distinguish settlement patterns in transportation analyses. Overall, a slight majority of households (51%) do not own a car (Jahn & Krey, 2014). And even though Berlin is the city with lowest car ownership in Germany, the existing 1.2 million cars would require a car lane of 7.200km length for parking alone (the street network is 5.452km long) (Reidl, 2019).

In the following, we first provide data on street allocation as collected for the case of Berlin. Second, we compare the observed street space allocation with allocation mechanisms and underlying ethical principles. This allows us to understand the different practical policy implications, which emerge from comparison of ethical principles and allocation mechanisms to observed data.



1. Alexanderstraße
2. Hermannstraße
3. Kurfürstendamm
4. Bülowstraße
5. Westfälische Straße
6. Köpenicker Straße
7. Fasanenstraße
8. Rochstraße
9. Boxhagener Straße
10. Brunnenstraße
11. Guerickestraße
12. Wilmersdorfer Straße
13. Wrangelstraße
14. Coppistraße
15. Senefelder Straße
16. Schiffbauerdamm
17. Friedrichstraße
18. Brückenstrasse

Figure 3. Map of Berlin focused on the streets surveyed: 18 Streets of Berlin surveyed to collect data on mode-wise street space and usage, user counts, social constructs (interactions and urban environment) of the streets. Map sourced from OpenStreetMap.

We measured street space allocation and counted user numbers on 18 streets in Berlin (Figure 3). These represent a variety of street types, section length averaged 250m (see Appendix for detailed statistics). The surveys took place between November and December 2018, during weekday off-peak hours. Summary statistics and street briefs are provided in Appendix C and D. Across all surveyed street segments, a large proportion of space was found to be dedicated to motorized traffic, confirming the findings of a previous study (Agentur für clevere Städte, 2014). On average, car lanes for driving take up 38% (min 12%, max 58%), and if street parking is taken into account, the allocation increases to 60% (36% to 83%). 30% of the space is designated for pedestrians. Seven streets have dedicated cycling and 5 streets have dedicated space for busses. Averaged across all 14 streets 6% and 4% of the total space is dedicated to cycling and busses respectively (for computation of allocation where street space has multiple users see Appendix E). Where dedicated public transportation space exists in a street it typically represents more than 15% of the space, and up to 31% on the Friedrichstrasse segment surveyed. Cycling represents on average around 10% where dedicated space is made available. In only one street, Bülowstraße - a very wide street - all five allocation classes were present. In cases without dedicated bicycle lanes or bus/tram lanes, bikes and buses can use the existing car lanes, but at risk of serious accidents, discomfort and congestion. In the subsequent analysis, we assume that space on shared lanes is shared among respective modes according to the modal share surveyed and apply a space occupation ratio of 12:3:1 (cars: bicycles: public transport). The derivation of this ratio is explained in the appendix.

User counts indicate a car user share of around 34%, 29% for pedestrians, 18% for public transport, and 16% for cyclists. Assuming that each parked car also has a user, results in a user share below 5% for car parking. Standard deviations across the different streets surveyed are large for all modes (Figure G Appendix).

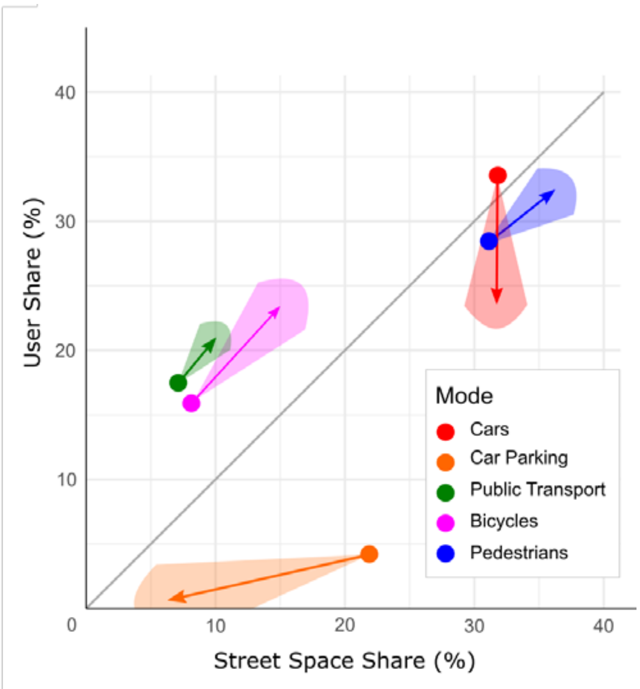


Figure 4. Street space by usage and space allocation for 5 modes presenting mean values of our street sample. Arrows indicate suggested direction of change, resulting from the discussion of ethical principles. Cones represent uncertainty on values. Values are indicative and require street-specific adjustments (Figure G in Appendix C).

Parked cars occupy most space against usage, whereas cyclists and public transit occupy least space against usage. Modes below the diagonal occupy a disproportionally large amount of space, modes above the diagonal occupy a disproportionally small amount of space.

We now investigate the relationship between user share and road space. The diagonal line in Figure 4 provides an indication of how much space each mode occupies relative to its user counts. In relation to ethical principles, this metric is most appropriate for allocation principles 2; 3; 6 and 7 (see Table 2). In particular, parked cars occupy, on average, 22% of road space but their assumed user share is at only 4%. In contrast, user shares for cycling and public transportation modes have been counted at 16% and 18% respectively, while the road space share remains below 10% for both modes. In this assessment road share and user share are fairly similar for driving cars and pedestrians.
We also compute allocation ratios of street space use (see Appendix F) confirming a strong bias towards allocating space to individual motorized vehicles and especially parked cars, to the detriment of public transportation and cyclists. Car users, on average, had 1.9 times the space

allocated to cyclists, and more than double (2.2) the space allocated to public transportation users, even when accounting for different space needs on shared lanes. The overall analysis reveals that most of the asymmetric space distribution is due to parked cars.

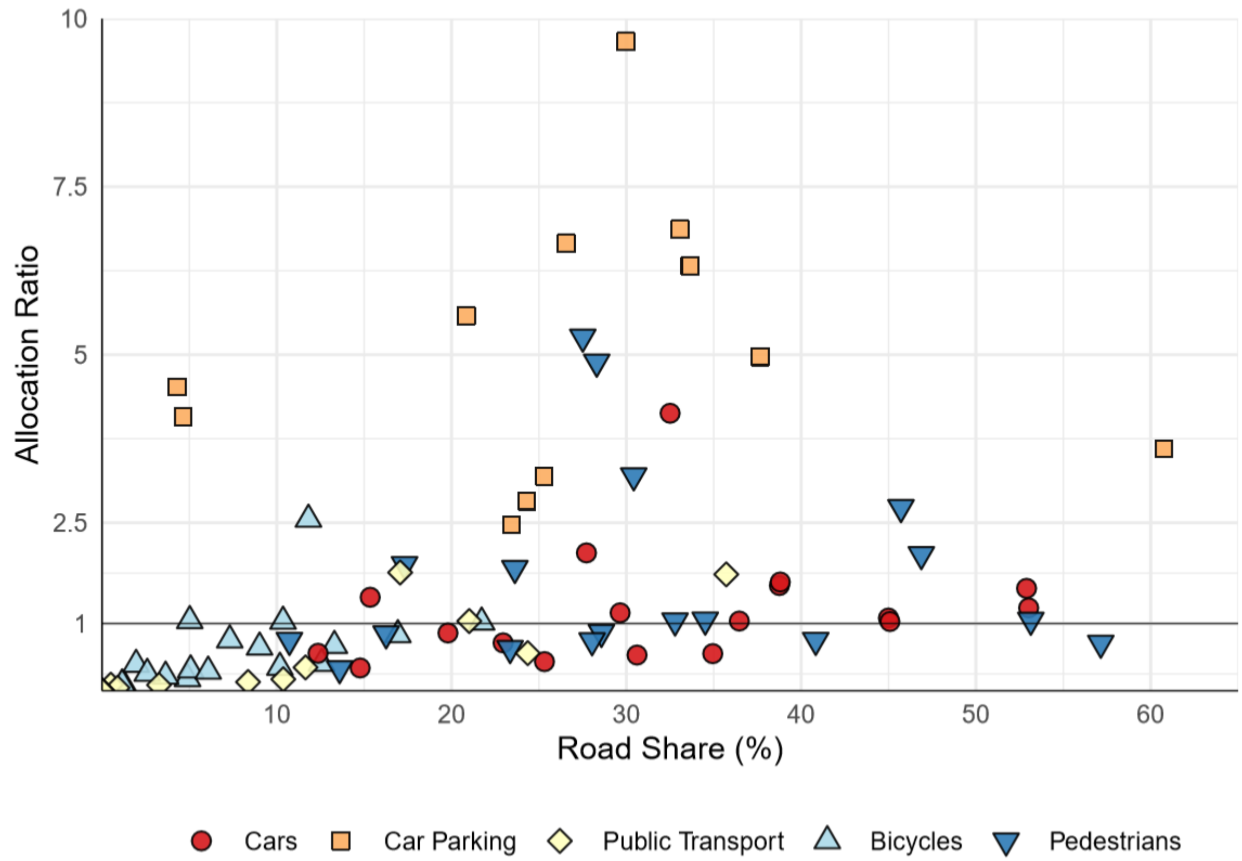


Figure 5 | Allocation ratios for surveyed streets. Parking dominates street space use in 16 out of 18 cases. In three cases, allocation ration for parking is outside the range depicted here.

Table 2 | Allocation mechanisms for fair street space allocation. Quantitative estimation from our sample of Berlin streets (comparable to other observations, such in (Agentur für clevere Städte, 2014). Derivation of quantitative values (AM 1-7) is explained in the Appendix. Qualitative values (AM 8-14) are provided by expert judgement within the author team.Underlying calculations are explained in Appendix G.

	Allocation mechanism	Definition of the mechanism	Street usage distribution (in %)					Evaluation
			Cars	*Car Parking*	*PT*	*Bicycles*	*Pedestrians*	
1	Grandfathering ("Status Quo")	Remain with the default conditions	32	22	7	8	31	Politically adequate, but not normatively Avoid costs of change
2	Equal modal share (by distance)	Space allocation as per modal share (distance-based)	33		47	14	6	Inadequate by consequence: distributional outcome does not correspond to the intuitive understanding of fairness and adequacy
3	Equal road space by modal share	Same as equal modal share, but applicable on road space only	32	4	17	15	31	Perhaps of interest, if shared mobility is added to public transit
4	Modal egalitarianism	Equal space for each mode	25		25	25	25	Gives ethical value to modes not people; unjustified by any ethical principle
5	Equal modal share (by trip)	Space according to modal share (number of trips)	34	4	18	16	29	Gives the same value to each trip; Perhaps of interest of shared mobility is added to PT
6	Efficient capacity	Maximize through flow: street space for higher capacity modes	2	-	69	12	17	Efficiency may be a normatively inadequate metric if outcome metrics are not or only very indirectly related to wellbeing.
7	Efficient capacity speed weighted	Maximize through flow weighted by speed	3	-	81	13	3	Efficiency may be a normatively inadequate metric if outcome metrics are not or only very indirectly related to wellbeing.
8	Economic efficiency	Allocate street space according to the economic value (prefer fastest mode)	-		+	+	-	Economic outcome normatively problematic, as many values and wellbeing dimensions are not reflected. Parking space for delivery and individual cars should be treated differently.
9	Auctioning	Allocate street space on the basis of who pays for this change	-/?		?	?	+/?	Economic outcome

10	Rawlsian justice ("streets for transport")	Improve accessibility for the least able (kids, elders, disabled)	?		+	?	++	Improves comfort for the least able at additional environmental cost
11	Local environmental efficacy	Minimize local pollution (PM, NOx, etc.)	-		-	+	+	Ignores individual wellbeing
12	Global environmental efficacy	Minimize climate change and resource use	-		+/-	+	+	Ignores individual wellbeing
13	Wellbeing	Enable a good life by providing services relevant for wellbeing, including subsistence, leisure, participation, and identity.	-		+	+	++	Gives more weight to wider notions of mobility, accessibility and possible use of street space. Normatively adequate in so far as it explicitly considers wellbeing. How to weigh different objectives is not answered. May require design solution.
14	Rawlsian justice of "street as places"	Improve the usage of streets for activities for the least able (kids, elders, disabled)	-		?	+	++	Improves comfort for the least able and improves environment at the cost of efficiency

4. Comparing allocation mechanisms

Here we compare both the overall empirical data on space distribution in Berlin's streetscapes and the in-depth street-specific case studies with the 14 AMs. Where applicable, we quantify the recommendations derived from the allocation mechanisms. Furthermore, we outline how the different allocation mechanisms would alter space allocation in Berlin. For this, we take the existing distribution of space as a basis and modify it according to the principles outlined in section 3.1. The results described here are summarized in table 2.

AM 1 - Grandfathering. With grandfathering, the existing street space distribution ratios would be kept, mostly benefiting motorized individual transport (cars).

AM 2 – Equal modal share by distance. Equal modal share allocates all the space across a road section proportional to total trip distance covered per mode (data here from (Agentur für clevere Städte, 2014)). Attributing space according to modal share strongly reduces space for walking and cars (by 25 and 21 percentage points), mostly to the benefit of public transport which would receive the largest share (nearly half of the street), and to a lesser extent to cyclists. The short distances traveled by pedestrians make their share of space drop to a low of 6% -- which is problematic due to the multiple roles attributed to walking areas as outlined in previous sections, and the significance of walking in general. The diminishment of space for walking shows that this allocation principle would lead to a drastic reduction in active transport.

AM 3 – Equal modal share on roads. This is similar to allocation AM 2, but excludes the pedestrian mode, and allocates only the non-pedestrian road space among the other modes. Cars occupy the greatest road space (87%) and contribute to a third of road trips, while half of road trips are made using public transport, which only gets 6% of the road space. Based on our data for Berlin streets, attributing road space by road modal share does not majorly change the road space allocation for cars (32%). However, the road space allocation for PT improves (17%) taking away space from car parking (4%). This allocation is more evenly distributed as sidewalks are not affected by the mechanism thus maintaining 31% of the space. Cyclists increase by 2 percentage points compared to the previous principle (AM 2).

AM 4 – Modal egalitarianism. This principle allocates the same space to every mode. With equal weight to each mode, this mechanism assigns ethical value to the modes and not to the people using them or the purpose or benefit gained from the individual modes. This is not obviously justified by any ethical principle. It also ignores mode efficiency. Relative to current street space, the egalitarian mechanism would increase street space for bicycles and public transport that often occupy little or no road space in cities. Given the varying street space share occupied by cars, parked cars and pedestrian pathways, the direction of change is uncertain, but cyclists and public transit would benefit the most.

AM 5 – Equal mode share by trip. This allocation principle would redistribute space according to the representation of each mode in per-trip modal share. Modal share by trip is a metric commonly used in policy-debates. Corresponding to the Berlin street data, we use the share of users per mode to redistribute the space. Cars and Walking take up the largest share with a percentage of 34% and 29%, respectively. PT and cyclists each have a proportion of around 20%. Space allocated to parked cars reduce drastically (relative to status quo) when applying the allocation mechanisms. The per-trip proportion of bicycle users is greater than the relative space dedicated to bicycle lanes in most streets. For example, in Guerickestraße, space for car driving is only 10%, while parked cars take up 38% of the road space. In contrast, 36% of observed traffic in the street is from cyclists, who have no dedicated road space.

AM 6 – Efficient capacity. This allocation mechanism prioritizes space-efficient modes. A larger share of street space should be allocated to modes with high capacity that maximize through-flow. This would highly benefit public transport and to a lesser extent bicycles, while it would drastically cut space allocated to cars. This mechanism is applicable in transportation planning, particularly in bottlenecks. Applying this allocation mechanism to Berlin street space, PT would occupy 69%, followed by walking (17%) and bike (12%), and cars would only account for 2% of space. This contrasts with reality, which gives most space for the mode with the lowest capacity. Street space is nearly always predominantly planned for cars, while the same cannot be said for any other mode except walking. Taking a Berlin example, Friedrichstraße is a shopping and tourist area where there is no dedicated bicycle lane but two shared lanes for cars (and underground public transport). Prioritizing space-efficient modes, such as bikes and e-scooters over cars, could alleviate congestion – and also local air pollution – that is caused by the relatively few car users in that street. This AM has considerable justification in general, but lacks consideration of high-value motorized transport (e.g. fire services). Further consideration of environmental and place-values are also not reflected (see below).

AM 7 - Efficient capacity, but speed weighted. Street space would be allocated by capacity as in AM 6, but additionally weighted by the average speed of each transport mode. Based on the assumption that higher velocity results in a more efficient movement, compared to the pure capacity as used in AM 6, more street space would be allocated to transport modes with high average speed. Nonetheless, cars would still obtain only 3% of the street space, while public transit benefits from this allocation mechanism. Pedestrians would lose even more space. This principle inherently discriminates against slower modes, which are enablers of streets becoming vivid spaces of social interaction, public activities and exchange. A purely transport-efficiency focused allocation mechanism would neglect the importance of street services beyond pure movement.

AM 8 – Economic efficiency. Street space is allocated according to the economic value (willingness-to-pay) associated with each km of a trip (libertarianism). This means mostly that this AM gives preference to the mode of transit which is the fastest. It is not utilitarian, as the failure to consider those who cannot pay implies that overall happiness or wellbeing is not maximized. Typically, mode-wise economic efficiencies vary daily, or hourly. It is therefore hard to provide a clear hierarchy of modes' efficiency ranges. Reallocation based on economic efficiency will see a reduction in space for walking and parked cars. Delivery vans, that presumably have economic value, would require the maintenance of some parking space, for short-term parking to deliver goods (and thus create economic value). Car dominance appears to reflect the prioritization of economic efficiency. Unpriced congestion is typically a sign that urban transport systems are managed inefficiently. In high-density urban settlements even low car usership can result into congestion across all models. In such circumstances, public transit and cycling rather than cars are systemically more efficient. Congestion charges and parking fees are the main instrument to achieve economic efficiency.

AM 9 – Auctioning. According to this principle, new street space is allocated on the basis of who pays for the change in space (libertarianism), following (Calthrop & Proost, 2006). In principle, it offers the opportunity to flexibly reallocate space to the highest value. However, according to other ethical principles such as a capability approach, or Rawlsian justice as fairness, street space is public space, and its privatization may not be desirable. The principle could be applied for parking spaces (which are public spaces squatted by car owners). For example, restaurant owners could bid for parking space in front of their dining spaces to expand seating opportunities. Another concern is that such an AM would amplify existing inequities by increasing the opportunity space for the better-off, while excluding the less well-off. As a benchmark of the value of space, an on-street parking space should cost the same as an off-street garage space. A private garage space currently costs about €30/month in outer districts and up to €200/month in inner districts (search at immoscout.de; July 17th, 2019). For comparison, in the extreme case of Manhattan, where real estate costs are on average 17,000 Euros per square meter in 2019, each 17-square-meter individual parking space has a virtual value of 289,000 Euros; free space attribution to cars yield a high monetary cost for society. One might object that free parking is socially inclusive. Yet, in locations were space has the highest value, such as in Berlin within the S-Bahn Ring, there are ample opportunity of mobility without a car; it is a pure luxury good.

AM 10 – Rawlsian justice for 'street for transport'. A Rawlsian perspective (difference principle) on "street for transport" implies that street-space should be allocated to maximize mobility opportunities for vulnerable and disadvantaged groups, which in many cases translates into space for the slowest mode (pedestrians). In terms of current street-space allocation in selected streets in Berlin the Rawlsian perspective is not amenable to ready-made quantifiable indicators. It instead offers general guidelines on where the status-quo falls short. Vulnerable and transport-disadvantaged groups such as children, seniors, and people with disabilities, require slow mobility environments that are safe from motorized intrusion, are highly accessible and have safe public transport. Berlin has mostly generous street space and many pedestrian areas are adequate for slow movement. Among cases investigated, Hermannstraße and Friedrichstraße are exceptions: shopping opportunities in these streets attract pedestrians but also squeeze them into the little available space. In addition, junctions are often unsafe to navigate, and turning cars pose a constant threat.

AM 11 – Local environmental efficacy. Local environmental efficacy prioritizes modes of transport with the lowest local environmental impacts like air-pollution and noise. AM 11 is compatible with both intergenerational equity and environmental values. Non-motorized modes of transport, such as pedestrians and cyclists, would therefore be preferred. However, modal shares of street space in Berlin is weighted heavily towards motorized vehicles. Only one out of the seventeen streets observed, Brückenstraße, had a higher percentage of total street space allocated to bicyclists and pedestrians than to cars, car parking spaces, and public transit. While a certain percentage of every street was available to pedestrians, biking infrastructure was found to be severely lacking, with less than half of the streets providing dedicated bicycle lanes. This AM would involve reducing the amount of space provided to motorized vehicles, to instead increase the size of sidewalks and establish of more bicycle lanes. The extent of the reduction of motorized vehicles and reallocation of road space would depend on the specific targets set, for example based on EU or national policy on air pollution or decarbonization. Limits would be imposed to reduce vehicle speeds, in order to decrease noise pollution and increase the safety of road users. One point of uncertainty is that of public transit, as the results do not distinguish between the types of public transit observed, and thus the extent of their environmental damage.

AM 12 – global environmental efficacy. Urban transport and space allocation is associated with two global problems: climate change and land-use change (which drives anthropogenic mass extinction). Priority is given to transport modes with the lowest GHG emissions, and to space allocation that constrains urban sprawl. At the vehicle level, smaller energy-efficient vehicles are preferred over larger ones, and electric and other zero-emission vehicles over diesel or gasoline cars. Bicycles, e-scooters and walking are vastly superior to even EVs, reflecting the large GHG emission footprint embedded in the production of batteries and vehicles (Hill et al., 2019). The average GHG emissions for different modes in decreasing order are: cars (100-143 CO_2e g/km tank to wheel), scooter/motorbike (77-107), standard diesel bus (75), Electric car (38), Metro (30.5), train (28), tram (23), cycle/on foot (0)(Sims et al., 2014). Thus, the space allocated to cars is reduced, that of PT might shift to tram/metro considering the capacity, while sufficient space is provided to zero-carbon modes like cycle and pedestrians. AM 12, like AM11, is compatible with both intergenerational equity and environmental values.

AM 13 – Wellbeing. The use of streets for transport is instrumentally very important for wellbeing. For streets, this includes a) access to health, education, jobs, leisure b) streets as playgrounds c) Vision Zero – i.e. the avoidance of (fatal) accidents, for example by focusing on high safety and introducing strict speed limits d) public space for social bonding and participation e) public space for experimentation (shared spaces) e) livable neighborhoods and f) freedom of movement.The high dimensionality makes this AM less suited to quantitative indicators, we therefore mainly rely on qualitative observations from different streets in Berlin.

Our empirical analysis suggests that participation and identity co-align best with the slow modes, and especially walking. One reason is that more pedestrian space encourages social interaction that underlie a sense of place (Jacobs, 1992). Qualitative observations from our fieldwork in Berlin suggests that the current infrastructure in most streets is not suitable for meaningful interactions. Instead more space for playful interaction is warranted (Stevens, 2007) . This AM also implies that current space allocation for car usage, both active car travel and parking is a significant burden, as it neither improves welfare nor capabilities, nor delivers the constituents of human needs. In fact , we find health burdens such as air and noise pollution, stress for both drivers and other transport mode users (especially active transport modes such as bicycles and walking), and economic externalities such as congestion and lower economic opportunities. Given these adverse impacts on improving the constituents of human needs or capabilities, this AM suggests a significant reduction in space allocated for car usage in Berlin. This AM also indicates that cycling and public transit should be prioritized over personal car usage, as both provide more interaction and sense of social identity.

AM 14 – Rawlsian justice for "streets as public spaces". The main objective here is to combine the concept of street space as public space (AM13) with the perspective of the most vulnerable. Greater allocation of public spaces increases the ability of the elderly, children and people with disabilities to relax, enjoy, and have meaningful interactions with others. This AM also stresses the need for street-space allocation for economic opportunities, especially for disadvantaged groups who may not be able to afford traditional spaces for their activities. These include hawkers, stalls, street-performers and micro-economic agents. Our qualitative observations suggest that most streets were unsuitable for social interactions of vulnerable groups. Playful interaction for all can be improved by street design.

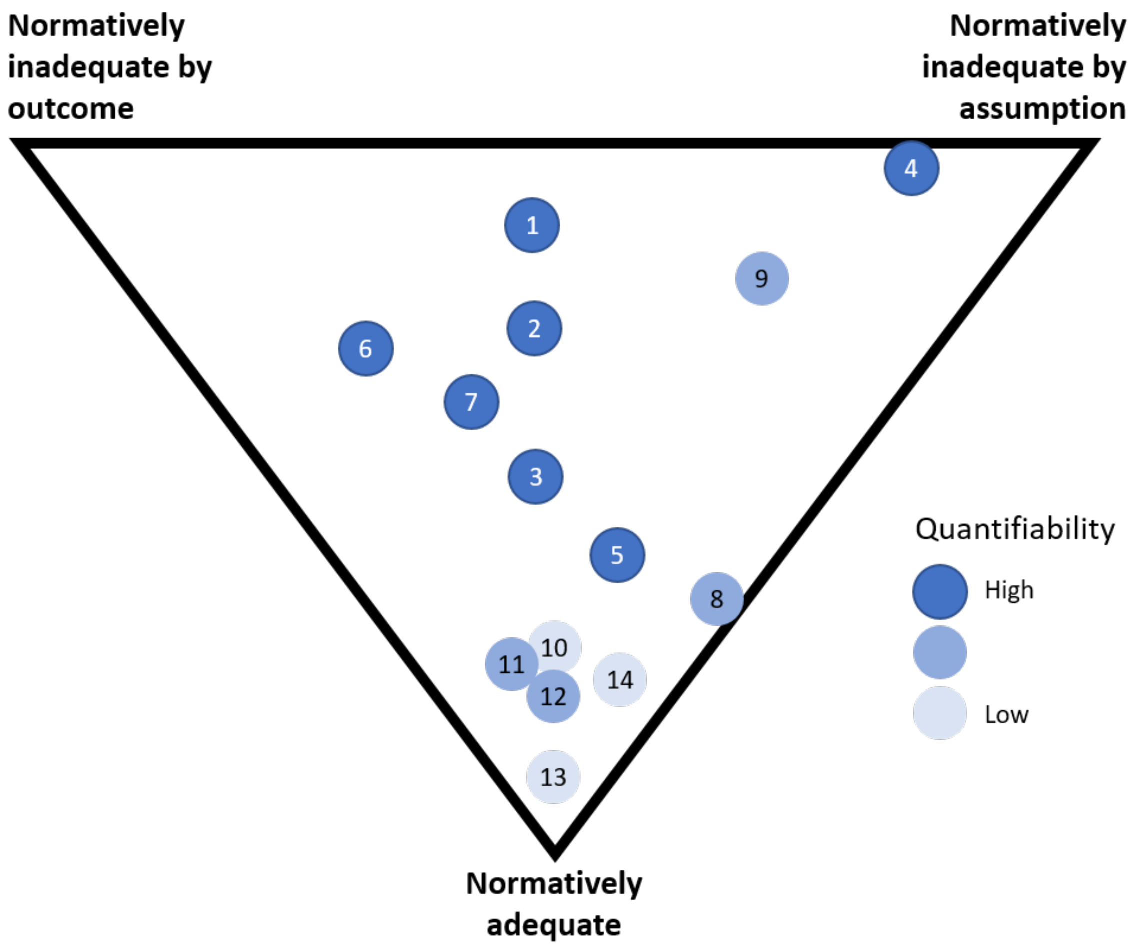


Figure 6. Normative adequacy of allocation mechanisms for fair street space distribution. Allocation mechanisms vary widely. Pure transport-based metrics are normatively inadequate, both by assumption and outcome. Economic efficiency is comparatively more adequate. Environmental and human well-being AMs are normatively most adequate but remain limited in scope. A combination of environmental, economic and wellbeing AMs could overcome this concern. Normatively more adequate AMs - that are necessarily high-dimensional and involve issues with open-system boundaries - are less quantifiable.

5. Discussion

We discuss first the rationale of the 14 allocation mechanisms, and second the wider justification of trying to allocate street space fairly.

5.1. Rationale of allocation mechanisms

We introduced 14 allocation mechanisms, derived from three normative perspectives, and evaluated their application for the case of Berlin. In half of all AMs (7 out of 14), we also estimated how each AM would quantitatively re-allocate Berlin street space. In the other 7 we estimated changes qualitatively. Here, we evaluate all 14 AMs relying on three criteria: 1) Is the AM well-grounded in ethical principles (normatively adequate by assumption); 2) Is the AM intuitively fair by outcome (normatively adequate by outcome)? And 3) How inclusive is the AM with respect to the various dimensions of current and future wellbeing? The results are summarized in Figure 6. Assumptions are understood as ethically inadequate, if the AM is only weakly founded in firm ethical principles. Outcomes are understood as ethically inadequate, if the application of the AM results in outcomes that are counterintuitive to just and balanced street allocation.

The ‘street-for-transport’ related AMs, especially those that only rely on traffic-related metrics, are normatively inadequate by assumption, but also by outcome, albeit with varying degrees. This is most evident in the case of AM 4 (modal egalitarianism). Modes themselves have no normative value and giving them equal share cannot be grounded in ethics. As absurd as it appears, in other cases, a mode centric approach is taken for granted in transport engineering, where providing spaces for cars (not people) emerges as a questionable objective (Jakle & Sculle, 2004). AM 4 helps to demonstrate the absurdity of this approach. Similarly, AM 1 (grandfathering) lacks ethical justification. Keeping everything as it is may appeal to status-quo bias, habits and human perception of what is ‘normal’, working well from the perspective of the political economy, but is neither supported by transport efficiency, nor environmental consideration, nor by human wellbeing. AMs reflecting modal shares (AM 3 and 5) are more interesting as they aim to provide each user equal rights to space, appealing to a basic understanding of fairness. However, these AMs insufficiently reflect the mechanics of public transit. Trams and busses operate under the principle of economics of density and rely on high ridership on minimal space both to be environmentally efficient, and financially viable. Hence, they require barely one third of all street space (AM 3) to operate efficiently (however see the emergent trend of shared mobility discussed below)[1]. The capacity perspective (AM 6 and 7) is even more extreme: because public transit is so capacity-efficient (Figure 2), more than two-thirds of space would be allocated to public transit, compared to a current share of only 3%. Such a high share for public transit is not needed.

[1] These AMs are also subject to an endogeneity problem. If street allocations are redistributed according to observed modal shares, modal shares will change with the modified space. This problem could be solved by an iterative process, assuming that modal shares and street space allocation will converge to a joint stable equilibrium.

However, this evaluation points to the vast potential in making the use of street space more efficient. Together, the purely transport-related AMs are normatively inadequate as they exclude important dimensions of human life, and for not directly targeting individual wellbeing or the public good; however, they provide some interesting food for thought.

The economic AM (AM 8) gives value to street allocation and would translate into making street space allocation more efficient, for example by requiring city-wide pricing of parking, and possibly congestion charging. In principle, it could also include environmental externalities. It is less clear how human well-being could be incorporated, if only because of difficulties of quantification. Clearly, the current practice of free parking could only be maintained if economic evaluations of transport efficiency (and environmental and wellbeing concerns) are continued to be ignored. Auctioning (AM 9) is a specific mechanism that may enable efficient allocation. It is however inconsistent with the notion of transport system as a public service. Auctioning may be applied in a limited context for places that are not required for mobility. For example, on a commercial street, local cafes and shop owners can bid on street-parking opportunities and allocate them flexible for public seating in summer and parking spaces in winter.

The Rawlsian perspective (AM 10) clarifies the importance of catering first for the most disadvantaged in mobility, which may include children, seniors, and disabled people, and thus prioritizes walking. Another implication is that public transit must be designed to be accessible for everyone. However, beyond this, the difference principle provides little guidance on precise allocation of street space.

The environmental AMs (AM 11 and 12) are crucial because they open up ethical allocation from purely transport concerns to the wider public good, reflecting local pollution (air quality and noise in AM 11) and planetary stability (AM 12). Yet, their pure application would empty streets from any motorized transport usage. It is hence clear that AM 11 and 12 are most valid in combination with other AMs.

The wellbeing allocation (AM 13) is most inclusive but also extremely difficult to quantify (Figure 6). It most explicitly combines the function of streets both as infrastructure for transport, and as public space, thus making explicit a core challenge for urban planning (c.f. (von Schönfeld & Bertolini, 2017)). It is the only one that explicitly considers the wider role of streets as public spaces that broadly serve a diverse suite of constituents of wellbeing, not only transport. That comprises streets as places to play, engage in public activities, and as places worthy of design through participatory and collective action. It is normatively most adequate as it is inclusive in purposes. Italso includes accessibility (the transport dimension), and is supported by most ethical principles (Figure 2). However, its broad perspective, also keeps it away from straight-forward transport metrics. Accessibility comprises access to various services: these can be provided by calibrated urban design with short ways, not requiring high street capacity or efficient transport kilometer delivery. Wellbeing is however silent on wider environmental public goods, such as climate change (Among Sustainable Development Goals, wellbeing is represented in SDGs 1-7, while other SDGs explicitly focus on planetary stability, and thus complement the wellbeing dimensions (United Nations, 2020)).

Rawlsian allocation considerations (AM 10 and 14) complement the picture and highlight the needs of the most vulnerable, including children, the elderly, and people with disabilities.

Our analysis focused mostly on people not freight. Freight relates mostly to the *streets for transport* perspective and can be relevant for wellbeing, e.g. when delivery goods have important service function, and especially when delivery goods enable access to the otherwise unavailable. Efficient delivery logistics can also reduce the environmental footprint compared to individual shopping. However, in practice free delivery services increase demand for goods that otherwise would not be purchased – scale effects counter any marginal benefit, adding to total environmental burden and increasing congestion. In Berlin, delivery trucks often double park, thus creating both congestion and unsafe situations. This is especially true for cyclists, who may be forced to transgress into oncoming traffic. AM 8 – the application of economic instruments for prioritizing the more important delivery – may provide some guidance for freight transport. A wellbeing perspective, favoring substantial street space for the slow modes and for play, may require a shift from 4-wheeled delivery trucks to 2-wheeled delivery services.

Together, our analysis of allocation mechanisms demonstrates that there is no single dominant normative perspective and resulting allocation mechanism to deliver fair street space allocation. The wellbeing AM 13 is most comprehensive and inclusive, but needs to be complemented by the environmental dimensions of AM 11 and 12 that are not always direct constituents of wellbeing. The economic allocation (AM 8) alone is insufficient but it can be very helpful in operationalizing the more overarching AMs 11-13. Nonetheless, operationalization should not be traded with inclusiveness. For example, playful street design, participatory design processes, and other dimensions that are hard to operationalize, should remain part and parcel of ethical allocation of street space.

The arrows in Figure 4 summarize a semi-quantitative and tentative interpretation of our discussion. The wellbeing perspective argues for more space for pedestrians, more precisely for streets as a place to be, e.g. for kids and seniors, hence the increased space for pedestrians. The increase is only moderate as Berlin already provides decent space in many instances. Public transit gains little road space – in those instances where busses are stuck in congestion. The high road capacity of public transit translates into few additional space requirement. Cycling gets additional space, and associated higher modal share, reflecting the need for safety, the environmental benefits, and the high wellbeing associated with cycling. Road space for parking cars is reduced dramatically, reflecting its inefficient and unjust current allocation. In contrast, road space for moving cars is kept constant. The spatial reallocation to other modes imply reduced modal share and less congestion.

5.2. Is fair street space allocation a good question anyway?

Nello-Deakin raise three fundamental issues questioning the rational of attempting fair street space allocation (Nello-Deakin, 2019). First, he charges that street space allocation based on observed modal share contrasts with intuitions about fairness, especially as the persistent outcome is the reduction of pedestrian share. Our analysis agrees with this concern. That is why an allocation mechanism that starts with a wider wellbeing perspective, and that prioritizes the condition of the slowest (based on Rawls' difference principle, or the Capabilities approach) is better justified. It also implies that allocation is often place-specific and not subject to any over-simplistic rule of thumb. Second, Nello-Deakin argues that different modes have fundamentally different characteristics. For example, cars require much more space than bicycles, mostly because they are faster. However, we argue that any allocation should start with people, not with modes, and that space allocation based on the needs of specific nodes is hard to justify from any human-centric fairness perspective. Third, he puts forward that streets are not only mobility spaces but also places. Again, we agree and concur by emphasizing the importance of giving high emphasis to a broader wellbeing perspective, such as presented by AM13, in guiding the allocation of space.

A last concern is that we focus our analysis on outcome metrics not on fair procedure (ethical principle based on social contract and fair discourse). This concern is valid: our evaluation focuses on (quantitative) outcome metrics. We suggest however, that a well-being focus that is place-specific and adaptive, is well suited to thrive on procedures that are inclusive to all (local) stakeholders. However the implications are not straight-forward: whereas everyone enjoys walkable or even playful streets, many also want to preserve their (free) parking space in front of their apartment. This indicates a particular type of urban common problem that requires more analysis.

6. Conclusion

This is the first paper to discuss justice and ethics of street space distribution, identifying three normative perspectives, breaking them down to 14 allocation mechanisms, and applying them to a selection of 18 street case studies in Berlin. It bridges the gaps between the literature on street space justice (Prytherch, 2018), pragmatic urban transport policy (Bongardt et al., 2013) and real-world measurement. The shortness of the paper format neither allows us to explore all ethical positions and allocation mechanisms in detail, nor does it give justice to all social, environmental, and economic considerations addressed in the vast literature relevant to our topic. But by bringing together ethical philosophy with urban transport design it elucidates a conclusion of high importance: current street space allocation contradicts all considered allocation mechanisms. As the status quo distribution of street space becomes more contested, ethical considerations are of increasing importance in justifying design choices.

Our study highlights the difficulty in applying even the simplified ethical principles for ensuring fair street space allocation, and that given practical concerns it is desirable to combine them together in pragmatic manner. Human wellbeing considerations are most inclusive but are often ignored in mechanistic transport planning schemes. Moreover, environmental considerations enter the wellbeing calculus only indirectly; and operationalization remains challenging. Hence, we argue for inclusion of environmental allocation mechanisms and instrumental use of economic efficiency within human wellbeing grounded allocation, while the latter remains dominant, especially in decisions on place-based street design.

7 out of 14 investigated allocation mechanisms provide quantitative predictions. While the others remain qualitative, there is potential to quantify these too. The predictions of each allocation mechanism vary widely but the trend across all 14 is unambiguous: There is a huge mismatch between current and recommended street space allocation. Specifically, all AMs reveal that cars are provided too much space, whereas bicycles require more space. We found that car users, on average, had 3.5 times more space available than non-car users. However, if only space for moving cars is considered, the difference in space per use is reduced to 1.6 times more space for car drivers over non-car drivers. This calculation demonstrates that most of the asymmetric spaced distribution is due to parked cars rather than driving cars.

One shortcoming in our analysis is that the quantitative measurements compare modal shares with modal street allocations, resulting in overly simplistic assumptions. Such an approach could simply reify existing patterns, which reflect the historic results of induced demand. However, even though induced demand is certainly prevalent in real street use, our quantitative analysis nonetheless suggests a considerable mismatch between road usage and allocation. Hence, our numbers serve as a conservative benchmark. Dynamic and spatially explicit models could take the next step and numerically explore stable equilibrium under a spectrum of different normative perspectives and allocation mechanisms.

These results have clear implications for policy and re-assigning street space: Allocating on-street car parking to bicycle lanes and bike and e-scooter parking will be justified from all ethical viewpoints. Our framework provides guidance on the direction, but not magnitude of change. A comparative look, comparing Berlin to Amsterdam, suggests that bicycle lanes should occupy 7% of street space (c.f. (Nello-Deakin, 2019)). A focus on re-allocating street space should be where pedestrians or cyclists encounters congestion or safety challenges. These are clear indications of insufficient space. Sometimes, especially in smaller streets, an improvement might be achieved by design, not by re-allocation. For example, streets could be redesigned as shared spaces that allow participation by all modes of transport, but that clearly signal, and mandate by design, slow speeds.

The most contentious part is the reduction of on-street parking, opposed by highly localized households with car ownership. They might argue: Car users require space for their cars so they can also use it in its active state for driving. There are two layers of considerations here. First, many houses have in-house parking; and there are 130.000 additional off-street parking places in Berlin. Second, and more profoundly, with the onset of shared mobility, the private car passively squatting public spaces for free is not required anymore. High quality mobility services can be delivered by shared bicycles, e-scooters, free-floating car fleets, and ride-pooling, all of which are already on Berlin roads. In fact, with more space available, shared mobility will be able to supplant rather than complement environmentally harmful modes, and thus achieve the sustainability benefits it promises (Creutzig et al., 2019). However, it will require stringent public policies to achieve this goal.

Applying fairness principles to street space allocation appears to be revolutionary. The application of fairness principles involves a significant transformation of traditional streetscape allocations that have largely gone unchallenged since the early twentieth century invention of the motorcar. The application of equity and efficiency principles related to mode share would prioritize slow pedestrians and semi-fast cyclists, but cut space allocated to cars. This contradicts the inherent logic of the ‘system of automobility’ (Urry, 2004), opposes law that subsidizes car driving (Shill, 2019), and counteracts existing behavioral biases and habits (Mattauch et al., 2015). Fighting these path dependencies is challenging, but with increasing awareness of streets as contested space it also emerges as a priority for decision makers. We wish mayors and administrations of cities the political navigation skills and a mindset grounded in fairness to succeed in these tasks.

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