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Degrowth in urban traffic.

Abstract

We apply the emerging paradigm of degrowth to urban traffic following Illich's (1974) notion of convivial tools and the division he makes between self-propelled transit and motorized transport of persons. Based on degrowth literature and the work of Ivan Illich, we define six principles of what degrowth of traffic would look like and from there we identify five socially and environmentally desirable criteria (degrowth desirability: institutional, energy and material efficiency, infrastructure, local environmental impacts and social impacts). To ground our analysis, we then add another set of criteria (personal viability: autonomy, comfort and safety, travel time, monetary cost, and health). Using secondary data, we take a multi-criteria approach on how a broad range of urban mobility options - including recently developed ones such as hybrid mobility and sharing schemes - perform with respect to these two sets of criteria. Our results offer new insights on mobility, based on degrowth principles and criteria. We highlight the viability and desirability of self-propelled transit for inner city traffic and of new mobility options for wider metropolitan mobility.

Keywords: degrowth, multi-criteria analysis, Ivan Illich, active mobility, urban traffic

Graphical Abstract

[Insert Figure 1 here]

Introduction: What would degrowth in traffic look like?

One of the ways to define degrowth is “an equitable downscaling of production and consumption that increases human well-being and enhances ecological conditions” (Schneider et al., 2010, p.2010). The term does not refer to a reduction in monetary flows -which would not make it any different than an economic recession. Rather, it is meant as a critique against the negative socio-environmental consequences of growth for the sake of growth and the policy and market imperatives this is manifested in. Degrowth advocates radical changes in modes of living (Meissner, 2019) that policy discourses often avoid (Wynes and Nicholas, 2018). Such changes could be induced with proper policies (Dietz et al., 2009) and are necessary since technological improvements alone will not be able to deliver sustainability (de Blas, 2020). Degrowth is an umbrella concept drawing from different sources: ecology, bioeconomics, critiques to development, theories of well-being, democracy justice (Demaria et al., 2013) as well as eco and radical feminism (Dengler and Seebacher, 2019); it is both concerned with environmental sustainability, economic viability and social aspects, like conviviality and justice. Degrowth points to a radical transformation in which societies’ “vital resources, infrastructures, and spaces are shared and held in common; technology is convivial and serves social purposes; resource throughput is minimized” (Kallis et al., 2018, p. 308).

Such a transformation can and must be achieved within cities, where most of the human population lives, and where a large volume of economic activity takes place. The transformation *must* be urban also because cities tend to be more affluent than their rural counterparts, so, if degrowth is primarily an imperative for the more affluent, then a specific focus on the urban is justified. This said cities and their infrastructurally-locked landscapes are highly uneven (Heynen 2014). Still, cities have large ecological footprint, and their impacts affect areas that span beyond their borders (Wackernagel et al., 2006). Tackling degrowth from an urban perspective then has the benefit of targeting growth and its problems in concrete territorial contexts. Moreover, degrowth *can* be urban because this is where many counter-cultural practices and grassroots

alternatives often emerge (Sekulova et al., 2017; Manning and Carlsson, 2010, SqEK, 2014; Cattaneo 2008, Widmer 2018).

Transport as one of the fastest-growing economic sectors is environmentally unsustainable and depends on large infrastructures: CO2 emissions related to transportation account for 23% globally (Sims et al., 2014) for 28% in the US (EPA, 2019) and for nearly a quarter in the EU. More than a decade ago, the European Commission warned about the need for a cultural change in mobility away from private motorized means (European Commission, 2007). Further impacts from transport relate to land-use change (Giampietro and Mayumi, 2009), air and water pollution, mining, and environmental conflicts (Scheidel et al., 2020). Worsened by the COVID-19 emergency which, even if contributing to less mobility, is also turning people away from public transport, the need for a *tout-court* transformation of mobility, particularly in urban areas, is more urgent than ever.

In this paper we apply a degrowth framework to assess different urban mobility options which we consider as (transport) *means*. These means go beyond the simple private vs. public dichotomy. We compare them with respect to a set of social criteria related to what degrowth in traffic can imply. Given what is desirable from a social perspective might not always be viable from an individual one, we also include a set of individual criteria to assess personal viability of mobility options. We do so in order to avoid that what is desirable from a degrowth perspective might not be acceptable from an individual one, which would hamper any democratic transformation. We ask: what could degrowth in urban traffic look like? What options are desirable and viable from a degrowth perspective?

The rest of the paper is structured as follows: the next section defines the theoretical framework, relating to Ivan Illich's work from which degrowth is inspired. An illustration of what is degrowth

in traffic is then offered where degrowth-relevant principles are listed, then related to a set of both desirability and viability criteria that are used for the analysis with respect to a set of mobility options. For the analysis we review secondary data from different sources, some at EU level, some based on national or local statistics. Although this mix of data sources might appear a shortcoming that lacks context specificity, we consider that the main aim of the analysis is not to provide any robust quantitative proof/evidence, but to give a rough indication for the setting up of a general theoretical framework that compares mobility options. Next, we take a desk-based multi-criteria approach in which the performance of each option for each criterion is expressed in quali/quantitative terms and a comparison among options is made. We conclude discussing relevant issues for degrowth of urban traffic.

Theoretical framework: Principles for a Convivial society vs. Technocratic disaster

Ivan Illich (1973) is remembered for his advocacy of a convivial society, that is a source of inspiration for degrowth (Vetter, 2017; Deriu, 2014; Kerschner et al., 2018). In alternative to the technocratic disaster, he defined it as "the result of social arrangements that guarantee for each member the most ample and free access to the tools of the community and limit this freedom only in favour of another member's equal freedom." (Illich, 1973: pp. 7). Socialism will only arrive in a bicycle, Illich quotes, and the bicycle indeed is a convivial symbol in the imaginary of a degrowth society (see e.g. Figure 2)

[Insert Figure 2 here]

Illich was basically against fast modes that he considered as alienating and illusory: for instance, an apparently fast speed that a car option might have must be re-calculated considering also time spent for parking, to get to and from the parking place and the time spent working for earning the income required to pay for its purchase and related fees. Considering total travel time and that spent in earning money, a car's real speed might not differ much from that of walkers or cyclist. Paradoxically, people spend a large share of their days working to afford trips necessary for

traveling to work, a core argument to the concept of degrowth.

Other than this, however, there has been little engagement with Illich's framework in relation to degrowth in traffic/transport. This paper contributes to the degrowth debate by building on Ivan Illich's work which, despite being a reference for degrowth advocates, is hardly mentioned in research on degrowth and mobility -for an exception see Taylor (2018).

What we find useful here is Illich's (1974) division of traffic in two categories: the transit of people, which is propelled by human power, and transport of people, which relies on external engines -and which can also apply for the movement of goods. He was very critical of the latter, particularly high-speed transport, public or private, because it requires a higher amount of energy, it becomes exclusive (with respect to those who opt for or are forced to a slow-speed mode of transit) and imposes the development of infrastructure (such as city bypasses, motorways junctions, high-speed railways, airports, terminals, etc.). This would degenerate into a radical monopoly of motorized transport over more convivial mobility options. By convivial tools, Illich meant "those which give each person who uses them the greatest opportunity to enrich the environment with the fruits of his or her vision". Instead, "Industrial tools deny this possibility to those who use them, and they allow their designers to determine the meaning and expectations of others." (Illich, 1973: 17). In this sense, human-powered means of transport such as the bicycle are convivial tools, but others, like motorized ones, are not. The "public vs. private" dichotomy constitutes, in Illich's terms, only one part of a higher-level dichotomy: "motorized vs. human-propelled". By pointing up mobility options such as walking and cycling -known in transport terminology as "active" modes- Illich is a precursor to degrowth, advocating for means of movement that imply a lighter social metabolism and have the potential for causing less social conflict and injustices while being more convivial.

A motorbike or a car are 10 or 100 times more powerful than a person walking or riding a bicycle and weigh much more, hence they are potentially much more dangerous and much more environmentally damaging. Since Illich wrote, new developments in electric mobility have occurred in the form of electric kick-scooters, e-bikes and other personal transporters. They have small engines of less than one horsepower so that they still require the human riding effort. For this they are more like active means and, rather than motorized, we classify them as hybrid (active joined with electric).

Despite these advances, a study of the potential of degrowth in urban traffic that could thoroughly compare the performance of different mobility options -public, private, active, hybrid- is still lacking. What would then be degrowth in traffic?

Inspired by Illich's framework, a preliminary exploration on "what is degrowth in traffic" and applicable in general or to the urban context, would include the following principles:

1.Degrowth entails less corporate -and eventually personal- property or use, and more **sharing** (Jarvis, 2019) and collective property. These are exemplified by the rise of the collaborative economy or by the need, in urban space, to limit private use of public space, as in streets and car parks. The sharing approach distinguishes between *having access to* vs. *having the property of,* in our case, urban mobility means.

2. Degrowth can be understood as **improving global environmental conditions** in relation to the service provided by the means of transport, an impact that has global effects such as climate change, resource exhaustion and biodiversity loss. For a given distance travelled, a person saves energy if travelling on an electric motorcycle rather than on a SUV, and a product has a lower

impact if transported with a cargo bike than on a lorry, or with a caravel than on a motorboat. In one case or the other energy consumed is very different[1].

3. Degrowth is critical of excessive and unnecessary development (Demaria et al., 2013). This relates to another criterion: **limit the overall development of mobility infrastructure** (limit space, limit investment over the long-term). Mobility means with different sizes, speed and operating frequencies will require different supports to operate properly. The larger or faster a transportation means, the more complex, costly, and technological advanced will be the infrastructure required. High-speed trains require specific railways; more frequent flights, larger airports; larger cargo boats, bigger harbors; faster cars, wider lanes. In the urban context a bicycle lane occupies less space, is cheaper to maintain and is more convivial than a car lane (Taylor, 2018) so that a mean could require overall less infrastructure than another.

4. **Improve local environmental conditions**: this is related to air-noise-visual pollution, local heat islands. Although particularly evident in large urban conglomerations affected by private motorized transport, it is relevant also in rural places i.e. where a large road goes through a village or an airport located in the rural space outside a city.

5. **Improve justice and inequalities**: deaths, injuries, fear, unequal distribution of social costs and benefits where those who benefit from using certain transport modes affect, directly or indirectly, the well-being of others who move in more socially sustainable ways, or simply slower. Heat island effects, air pollution, noise pollution and casualties from traffic accidents constitute causes of increased mortality and morbidity. Also, large traffic infrastructure makes urban space scarcer.

[1] Clearly, trading goods on a caravel rather than on a cargo might be desirable from an energy efficiency perspective, but not viable from a business perspective.

Speed -that according to Paul Virilio (1986) is the engine of destruction- is generally expensive, and often partly subsidized but not in a redistributive manner. Richer people can drive bigger cars, pay for pollution charges, fly, use high speed trains and therefore, pollute more while the removal of trees along roads that provide shadow, or the new infrastructures like flyovers and tunnels, often negatively impact walkers and cyclists. In this sense, degrowth in traffic could be related to the environmentalism of the poor (Martinez-Alier, 2002). The perspective of "justice in the streets", a slogan of the social movements (Ecologistas an Acción, 2005) related to how some mobility users are a source of injustice while others are victims is still missing in the academic debate and this paper makes a case for it. It refers to a novel aspect in literature, related to inequalities arising within users of different mobility means and of transport infrastructure. For instance, policy discourses are more centered on the environmental virtues of certain mobility options, but not on the injustice that also lays behind these.

6. Degrowth in traffic can simply be understood as **posing limits on** overall mobility: affected by ever increasing mobility, faster travelling to more distant places with more technically and economically accessible means has implied over the past few decades a growth in hypermobility which, according to Adams (2007) will lead to a more hostile, dangerous, paranoid, and polarized society and a less fit, democratic and culturally varied one. A way to understand degrowth is, therefore, as having fewer people and goods needing to move around, at a lower speed, or less frequently, or over shorter distances. For the urban case, it could be referring to any of the reasons associated with urban mobility, such as commuting to workplaces, transporting goods, going to school, personal care transport, shopping, sports, leisure, etc. An open question remains whether the need for people to move around should degrow in the urban case and assessed in terms of mobility options. We argue that mobility *per se* is not a problem and it should not degrow for the sake of degrowth; rather, informed by Illich, mobility is a mean using tools that can be convivial,

just or polluting[2]. However, since convivial self-propelled mobility means require certain physical effort and are likely less comfortable than motorized ones, a modal shift towards them would likely imply an overall decrease in mobility.

Methods: Criteria and indicators to assess mobility options according to degrowth desirability and personal viability.

In this section, we define the set of mobility options, and propose criteria and indicators to assess their general desirability according to degrowth principles, and their personal viability.

Informed by Illich, we define a range of mobility options, pertaining to two broad categories: motorized (including private and public options) and self-propelled (including active and hybrid). Each is made of several options including pooling, sharing, electric and combined sharing & electric possibilities that have recently been developing. Table 1 presents the options.

[Insert table 1 here]

Next, we specify a set of criteria and indicators we use to assess the above mentioned degrowth principles 1-5. We do not take into account principle 6 because it does not depend as much on mobility options as it has more to do with its drivers, like for instance mobility for consumerism vs. mobility for conviviality, and this is beyond the scope of this paper.

Degrowth desirability criteria and indicators.

1 Institutional (related to the principle of less private ownership and use (Jarvis, 2019)): three indicators can determine this criterion:

a) Multiple users of the mean. We consider that the more a mobility option is likely to be shared, either sequentially (**sharing**) or simultaneously (**pooling**), the more aligned to degrowth it is.

[2] The case of cycling without age (https://cyclingwithoutage.org/) is paradigmatic: a care-based, non-commercial option performed with convivial tools is certainly a type of mobility that in a degrowth society should grow

b) The likeliness of the **ownership** to be public, cooperative, or collective (from a degrowth standpoint more desirable) instead of personal (neutral) or private for profit (less desirable).
c) Since the "sharing/collaborative economy" is an undefined continuum that spans from purely collaborative cultures to platform capitalism (Srnicek, 2016), the type of **culture of sharing** that is likely to develop around options is also valued.

2 Global environmental impact Less energy inefficiency, and not simply less GHG emissions - renewables produce their environmental effects (Giampietro and Mayumi, 2009)- is a suitable sub-criterion for degrowth in global impacts, so that we calculate **energy consumption** per person per kilometre over the lifecycle of the option. A second sub-criterion is material use and is informed by the notion that batteries for electric mobility have a short lifespan (Moreau et al., 2020) and by the fact that two orders of magnitude separate the material requirements of light vs. heavy means.

3 Infrastructure For an urban context we focus on space used up by mobility infrastructure because this resource is socially most conflictive and economically most scarce. The indicator follows the approach of **time-space consumption** -measured in square meter hours, m^2h-, used by Drut (2018) which sums static space-time consumption (used for the time the vehicle is parked) with dynamic space-time which combines the space occupied by the vehicle in motion (proportional to the speed) with the time spent using the section of the road/lane/footpath/rail (inverse to the speed).

4 Local environmental impacts. We consider **heat island effect, air and noise pollution**. Air pollution, mainly related to urban transport, contributes to over 3 million premature deaths globally (World Health Organzation, 2016). There is mounting evidence that air pollution is related to higher risk of COVID-19 contraction (Wu et al., 2020; Pozzer et al., 2020). Noise

pollution contributes to altered quality of life while excess heat is a source of premature deaths.

5 Justice and equity. As per our theoretical framework this criterion applies at the city level and at the street level. How urban mobility and its infrastructure affect other urban uses of the space and quality of life of all citizens -and which mobility modes are more responsible for these effects (urban environmental justice); and then how this is also a relational criterion of how mobility means and the required infrastructure affect each other (justice in the streets) and end up creating radical monopolies (Illich, 1973). Some examples of injustice in the street are: exclusive infrastructure where only private means are allowed such as tunnels, freeways, or city bypasses; unequal allocation and use of street space among different means; imposition of traffic lights -that in car-free cities would not be as many; adverse physical and psychological health effects among mobility users (accidents, fear). Since fear is a recognized factor against the use of active mobility (Generalitat de Catalunya, 2019), **momentum** of a mobility option -the mass of a vehicle times its speed- is a suitable indicator: the larger the momentum (that is, the fastest and the largest the mobility mean is), the stronger the fear felt by users (or potential users) of smaller and slower means exposed to traffic. In other words, if cars were not so fast, neither so heavy, nor so many, then the sense of fear, vulnerability and insecurity would be lower.

In the fourth step we identify criteria that evaluate what is personally viable to avoid the fallacy of wishful thinking. In fact, using results to select mobility options that are desirable but then impractical to adopt could consign degrowth proposals as unrealistic. Also, from a policy perspective, personal criteria exert a considerable influence on mobility choices. Based on a review of institutional reports that we have taken from Barcelona, a city with notable traffic-related problems, (IERMB, 2020; Generalitat de Catalunya, 2019 and Ajuntament de Barcelona, 2019a) and on a similar work done by Drut (2018), we identify the following.

Personal viability criteria and indicators

To define which criteria should be included in this group, we start acknowledging that autonomy has been treated by degrowth thinkers and their inspirators (Deriu, 2012; Castoriadis, 1975). Next, we also consider that "fast, cheap and safe" are three valuable attributes for transport users; in fact, several of the institutional mobility reports we have consulted deal with these issues (European Commission, 2007; Generalitat de Catalunya, 2019; Ajuntament de Barcelona, 2019). Finally, adverse health effects of mobility means are also a relevant and recurrent issue in transport assessment (WHO 2016 and 2020).

6 Personal autonomy. Freedom is a core principle within the western democratic tradition in a way related to the infinite pursuit of growth (Deriu, 2012); however, it is also compatible with the degrowth-relevant notion of autonomy (Castoriadis, 1975), intended as self-emancipation and the capability to not rely on external authorities. In the context of mobility, autonomy implies the right to choose for as many mobility options as possible. Then, within each option, it refers to a) ready-availability, that is the freedom of choosing when to begin a trip, of allowing to have intermediate stops in the journey (i.e. taking a child to school on the way to work), b) spatial accessibility: which parts of the city can be reached, c) if needed, parking, d) which weather conditions limit the use of the vehicle and e) if applicable, the risk of the vehicle being stolen while parked.

7 Personal comfort and safety. This has to do with comfort during the trip; it includes a) physical (i.e. sitting down; adaptation to adverse weather events, exposure to accidents) and b) psychic (i.e. the mental attention required if driving vs. the distraction allowed for a passenger, intimacy, risk of harassment). Safety has to do with the likelihood of arriving safe at a destination. We will not consider the safety of a mobility mean *per se*, but in relation to the means that share the same infrastructure (i.e., how safe a bicycle is mainly depends on which other means circulate on the same road).

8 Travel time. Using door-to-door estimates, we consider that, from the perspective of individual choice, the shorter the travel time, the better.

9 Monetary cost. It is the combination of a) direct running costs, b) eventual maintenance costs and, for private means, c) the eventual cost of purchasing the vehicle. This criterion is also valid from a degrowth desirability perspective: higher monetary costs often translate into higher environmental impacts and into increased dependence on a paid-job, likely within the capitalist system.

10 Personal health. It has to do with the possibility to combine the mobility option with physical exercise. Physically healthy people are more likely to have a stronger immune system. It is also compatible with degrowth desirability because it contributes to increased well-being and quality of life.

In summary, degrowth of urban traffic can be accomplished with the adoption of mobility options -and the personal, political, or institutional choices that are behind- that respond to the following questions addressed by the indicators above:

- Does a particular mobility option contribute at the institutional-economic level to the development of the collaborative economy, a culture of sharing and collectivization?
- Does it, from an environmental perspective, improve global and local environmental conditions, through a more efficient energy and material use?
- Does it require from the urban planning and development perspective to less infrastructure overall, that can free scarce urban public space for other uses?
- How does it, from a social perspective, contribute to urban environmental justice and injustice in the street?

- Is it also a viable option in terms of personal autonomy, comfort, safety, travel time, monetary cost, and personal health, so that its adoption will be more likely to happen?

The more positive are the answers to the first four questions, the more desirable will the option be from the degrowth perspective. The more positive the answer to the last question, the more likely the option will be adopted and/or accepted by the public in case transformative policies towards degrowth of urban traffic were proposed.

In the next section we show how these criteria could be applied to assess the performance of different mobility options using secondary data from the literature and of ranking them based on the degree to which a given criterion is being achieved

Results: An assessment and ranking of mobility options according to degrowth in traffic.

For each desirability and viability criterion we define the performance of each mobility option and a ranking. We do so by offering arguments and evidence that support our evaluations which are then visually synthesized in a matrix (Table 12). The performance of each option is ranked using colours, with red (**bold underlined**) meaning very poor performance, orange (*italics*) quite poor, yellow (underlined) moderately good and green (**bold**) very good. A computational process such as a multicriteria method would have required other analytical steps beyond the scope of this paper (Munda, 2004). In fact, our aim is to relate degrowth with urban traffic and to provide guidance to the problems of mobility and space use in cities. Offering more robust answers would be the task for further research.

1. Institutional criterion. Qualitative evaluation

a) Multiple users: public transport options perform well together with shared (e-)cars/e-motorbikes/(e-)bicycles and carpooling options. If done in company, walking or cycling can also score high.

b) Public/cooperative ownership: public means are scoring better than other options. Shared (e-)bikes only when owned by municipalities. Cooperatives owning shared car /motorbike systems will certainly do better than corporations, but now it is quite unlikely that they would constitute the majority of sharing schemes. This indicator cannot apply to walking. Finally, personal ownership is considered better than corporate, and private (e-)cars are more likely to be owned by enterprises than motorbikes or even more likely than active and hybrid personal means.

c) Fomenting the collaborative economy/ a culture of sharing: cars and motorbikes require the operator to hold a driving license, insurance often might only cover one driver: these are expensive means, less likely to score high on this indicator. Instead, active and hybrid means can easily be lent to others. Private means also score low with respect to their likely contribution to a purely collaborative economy as the examples of Uber, Cabify and similar platform capitalism corporations show. Instead, bicycles are better placed -as an example, see Bradley (2018) on bike kitchens, collaborative economy and P2P in relation to degrowth and technology. Public transport means, being subject to the impersonal management of public authorities are less likely to contribute to the collaborative economy.

In summary, private vehicles that are not shared/pooled appear in red because they do not fulfill any of the three sub-indicators here analyzed; shared options appear in orange because they foment a culture of sharing, however, they will quite likely be owned by for-profit private enterprises. (Shared) kick e-scooters appear in orange as they fulfill sub-indicator a (for being small they can easily be lent to others, so they allow multiple users). Public transport options appear in yellow as they fulfil the sub-indicators a and b. The remaining active and hybrid means perform well in sub-indicators a and c, while they are neutral with respect to b. Tables 2a and 2b summarize the results.

[Insert table 2a and 2b here]

2. ***Energy efficiency and material use. Quantitative and qualitative indicator***

Energy consumption is related to the power of the vehicle (mass times speed) divided by the number of passengers in the vehicle, and to the lifespan of the vehicle -or its components. It is also quite closely correlated to material consumption as a larger mass requires more energy to move it. Motorized transport has a higher energy consumption than self-propelled. For their low occupancy rate of about 1.2 passengers/car[3], cars and e-cars are using more energy per capita. Public transport has a lower per capita energy demand, hybrid even lower -although the short lifespan of batteries decreases this performance- and active nearly null (only the body energy). This qualitative ranking can be supported by quantitative data taken from a Spanish-based organization specialized in transport analysis[4]; these data can easily be applied to other EU cities.

Energy demand per passenger is for diesel/petrol cars 3.63/4.55 MJ/km respectively, for carpooling (i.e. 2-3 passengers per car) we can estimate half of these; for motorbikes 1.78 MJ/km; for buses 1.25 MJ/km; for tram 0.77 MJ/km; for metro 0.43 MJ/km and for train 0.35 MJ/km. Hybrid mobility options have a very high energy efficiency[5].

Material use is between moderately large and very large for private vehicles, with electric options scoring worse than fuel ones because of the short battery lifespan. It is small for buses and moderate for rail options -because of their large size and the infrastructure requirements. It is nearly null for active options and between small for and moderate for hybrid ones -with individually owned e-scooters having the largest material impact.

[Insert table 3 here]

[3] See, for the EU average, the occupancy rate study by the EEA, table 6.1 - commuting trips. https://www.eea.europa.eu/publications/ENVISSUENo12/page029.html

[4] Own elaboration from table at page 3 of https://transportpublic.org/images/pdf/20110927-cursa_explicacio_resultats.pdf

[5] For instance, a standard e-bicycle battery has a capacity of 11Ah at 36V. This is equivalent to 0.396 kilowatt-hour or 1,65MJ for an autonomy of about 40 km. It results in 0.04 MJ/km. In fact the power contribution of the engine (250w) is 2-3 times less than that of the biker. For an e-scooter, where the passenger is not pushing, we can assume that the energy consumption of an e-scooter might be 2-3 times higher than that of an e-bicycle (0.1 MJ/km). For shared (e-)bicycles something should be added for the fuel consumption of the lorries used to reposition (e-)bicycles in empty stands, but this figure would also not add much to the general value which remains 1-2 order of magnitude lower than private vehicles. It should be acknowledged the energy impacts associated to the production and disposal of batteries increase with the size of the vehicle and of the battery that powers it.

*3. **Time-Space occupation**. **Quantitative indicator***

Following Drut (2018) -based on a 10-km return trip- one car with an occupancy of 1.2 passengers uses 93.7m^2h; carpooling, with 2.5 passengers, 45m^2h; (e-)car shared, with 5 uses per day, 39m^2h; motorbikes 21m^2h; buses with dedicated lanes 12m^2h -we consider tram with dedicated rail space to be twice as fast as the bus, so 6m^2h; (e-)bicycles/scooters 10.6m^2h; shared e-motorbikes 10m^2h; shared (e-)bicycles/scooters, with 5 uses per day, 5.2m^2h; buses with no dedicated lanes and metro, 3m^2h -we assume the train to use the same space as the metro since it normally runs underground; walking 2m^2h[6]. It should be noted that the difference in time-space for a private car versus walking is nearly 50-fold; versus public transport is more than 30-fold; versus bicycle/kick-scooters is 9-fold.

[Insert table 4 here]

*4 **Local environmental impacts. Qualitative indicator**.*

a **Air pollution**. The main pollutants in cities with negative health consequences are related to the emission of NOx, PM 2.5 and PM10. It is quite complex to quantify air pollution per passenger/kilometer for the mobility options and it suffices to say that while combustion engines contribute to NOx and PM emissions -to varying degrees according to the category of the vehicle (Euro I to Euro VI), other vehicles such as e-cars and e-motorbikes do still emit PM via tyre, brake and road surface wear in a quantity proportional to their mass[7]; in fact the development of pollutant efficient combustion engines such as the Euro VI category only contributes to a reduction in exhaust emissions.

b **Noise pollution** and **heat island effect**: although quantifying it in decibels or in excess heat goes

[6] In Drut (2018) shared e-motorbikes (e-)kick-scooters and rail modes are not included. Shared vehicles are estimated to use less than half of the m^2h because they spend less time parked; with this logic, we can assume that shared e-motorbikes use 10 m^2h; kick-scooters can be assumed to be a bit less than bicycles -lower speed although they use the same parking infrastructure provided by the municipality- e-scooters and shared e-scooters can be assumed to use the same m^2h than e-bikes and shared e-bikes.

[7] see for exhaust emissions https://www.eea.europa.eu/publications/emep-eea-guidebook-2016/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i and for non-exhaust emissions https://www.eea.europa.eu/ds_resolveuid/0QCUR26EVW

beyond the scope of this paper we can state that combustion engines and vehicles moving faster are the noisiest and hottest, with motorbikes at the top, while underground transport, hybrid and active options are the least noisy and, for having no engines or at worst more energy-efficient electric engines, are those producing the least excess heating per unit of service.

For the ranking, smaller vehicles imply less noise and less emissions per person; electric engines imply less noise and less emissions -including CO2- than combustion engines. Our ranking would then be: car, motorbike (extremely high impact per passenger), e-car, car pooling, shared car, shared e-motorbike (high impact), bus, light train (moderate/low impact), tram, metro, (very low impact) (shared) e-scooter, (shared) e-bicycle, (shared) bicycle, kick-scooter, walking (no or negligible impact).

[Insert table 5 here]

5 Justice and equity. Qualitative & quantitative indicator

The lack of green areas in many cities can be attributed to excess allocation of urban space to streets that, in turn, are monopolized by relatively few car users. The rankings associated with the time-space occupation indicator and to local environmental impacts are a good proxy for urban environmental injustice, therefore, cars would be the main source of injustice, followed by motorbikes and shared e-motorbikes. Public transport, active and hybrid options would not contribute to urban environmental injustice, due to their low need for public space and low impact. An exception are shared schemes as so far, they have contributed to shaping the smart city image which, in turn, is not for the benefit of poorer classes and can contribute to gentrification while their providers tend to be growth-oriented corporations (Médard de Chardon, 2019)

For **justice in the street**, the average size of a European car was, in 2015, 1,38 tons (EEA, 2016, p.24). When circulating at a speed of 50km/h, a person in a car has a momentum of 74 tons km/h. A pedestrian (0,07 tons at 5km/h) has a momentum of 0.35 tons km/h, more than 200 times less. A person on a bicycle or e-scooter (0,08 tons at 25km/h), has almost 40 times less momentum than a

car, but almost 6 times more than a pedestrian. Active and hybrid modes are therefore victims of injustice generated by larger means, in particular private vehicles which constitute the majority in the streets.

Further, congestion which slows down traffic is generated by the large time-space occupation of cars that negatively affects buses which, in these terms are also suffering from injustice in the streets. The rest of public transport means, having their own infrastructure and not requiring much space, are neutral with respect to justice and equity.

[Insert table 6 here]

6. ***Personal autonomy Qualitative indicator***

This is maximized in private and active/hybrid modes which are readily available at any time and minimized in public ones. For sharing modes ready availability is reduced (for instance the service offered by some bike sharing systems is limited within municipal terms and not available during night time). For shared cars parking spaces can be more available than for private cars (often they have reserved parking places). In case of pooling availability is further reduced -it depends on the possibility for the supplier of transport to meet demand and vice versa. However, new ICT and the apps that are developed can reduce the disadvantage, particularly in densely populated urban areas. Two-wheelers allow more freedom on congested roads but have a weather disadvantage[8]. Non-motorized vehicles are allowed in pedestrian areas and footpaths; large, motorized ones are allowed in city bypasses, tunnels, and highways. Smaller vehicles can be parked more easily, and lighter ones can be taken inside buildings or on certain public transports but also, they can be stolen more easily.

We consider that a justified ranking could be: walking, two-wheelers -no congestion which is more frequent than adverse weather events and with motorbikes ranking better as they cannot

[8] In case of rain having to opt for another mode than a two-wheeler implies a limit in freedom. But using it and getting wet implies a limit in comfort.

easily be stolen (which in surveys constitutes a factor against the use of bicycles) and with privately owned ranking better than shared or pooled ones. Then four wheelers (affected by congestions and limited parking) and finally public transport and, among its modalities, those with a higher frequency and stops/stations ranking better.

[Insert table 7 here]

7. Comfort and safety. Qualitative indicator

Comfort is lower for active modes; except for walking, the effort of riding and the rider's position (also common to motorbikes) are the principal limiting factors. For e-bikes/scooters the effort can be less. A trade-off exists with respect to cars vs. public: cars are more comfortable but need the attention of the driver, which is often the only user of a car. But intimacy is lower for public means, even more so for women or the elderly who are more likely subject of sexual or verbal harassment. Safety is often mentioned as a main concern limiting active mobility (Generalitat de Catalunya, 2019), although it would not be so if active modes did not have to share the same space with private motorized means, as already highlighted in the justice criterion. Supposing that in the medium-term the CoVid-19 problem will have been properly addressed or solved, it is highest for public transport, then the car, then walking and then, for the rest of modes, it is proportional to the size of the vehicle[9]. Shared vs. private ownership is indifferent.

The ranking would then be: tram/bus; metro/train (for some train accidents or risk of terrorist attacks); carpooling; (shared)(e-)car; (e-)motorbikes; walking; (Shared)(e-)bicycle/scooter, bicycle; kick-scooter.

[9] For the case of Barcelona, according to the 2015 mobility survey, 128 out of 141 deaths occurred between 2011 and 2015 and about 92% of serious injuries (n=1176) affected the vulnerable collective (walkers, bicycle and motorbike riders). We do not know, however, how many were due to accidents with larger vehicles. https://ajuntament.barcelona.cat/ecologiaurbana/sites/default/files/DADES-BASIQUES-MOBILITAT_2015_Resum.pdf

[Insert table 8 here]

8. Travel time. Quantitative indicator

Dekoster and Schollaert (1999) show that for door-to-door trips of up to 5 km in length the bicycle has the shortest travel time, between 5 and 9km is the car -but only 1 or 2 minutes faster- and beyond that distance is the train (See figure 3). Unfortunately, in their study metro, motorbikes and hybrid modalities were not considered and would likely be faster than train, car, and bicycle respectively. Supposing an average distance covered of 5-10 km, which is quite realistic for most trips within medium-small European cities, motorbikes and hybrid options have the capacity to be the fastest.

The ranking, for the 5-10km distance, would then be: (e)-motorbike; (shared) e-bicycle; (shared) e-scooter; (Shared) (e-) car; (shared) bicycle; carpooling; metro; train; tram; bus; kick-scooter; walking.

Dekoster and Schollaert (1999) also do not contemplate longer trips, i.e., 10-20km long, which often constitute mobility to and from the city, and in which private modes are the most frequently used option. Also, beyond the inner city boundaries public transport is often not easily accessible and hybrid options are cut out from the access to speedy infrastructure such as bypasses and highways -we deal with this issue in the discussion.

[Insert figure 3 and table 9 here]

9. Monetary cost. Quantitative indicator

Costs can vary a lot among different countries, so we will use data from Barcelona-Spain (though in any case we do not expect the ranking, as distinct from precise costs, to depend so much on the place of reference). For cars, the average cost per kilometer over the 2014-2019 period was 0.27€/km[10]. This is the average reimbursement paid by enterprises to employees' driving their own

[10] Value taken for Spain https://www.captio.net/blog/a-cuanto-te-pagan-el-kilometraje-compara-con-datos-reales

cars, it is a conservative estimate though, because the annual depreciation of a car is not fully included in these statistics -only the cost for the replacement of parts that break. Applied to the case of a 5-10 km trip, and 1.2 passengers per vehicle the personal cost for a 5-10km trip would be in the range of € 1.12-2.25 for a car. This is a conservative estimate that does not include the cost of parking. For a motorbike or carpooling with 2.5 passengers/car we can assume half of this cost. For shared options, the cost, per minute, is about 0.2-0.25€/minute for (e-)cars e-motorbikes and e-scooters[11] (higher for motorbikes because they move faster in the traffic): at average speed of 21km/h[12] a 5-10 km trip would cost €3-6; for shared bikes the cost is 50€/year and then free for each trip up to 30 minutes long (7.5km) -if used 400 times per year (i.e. twice per working day), the cost would be 0.12€/trip, or 0.18€ for shared e-bikes[13]. For privately owned bicycles, purchase and maintenance can cost around 85€/year while for e-bikes, charging purchase and maintenance costs are equivalent to 174€/year; these costs, if are distributed over 400 trips[14], are equivalent to 0.21€/trip and 0.43€/trip respectively; we can assume that an e-scooter has the same cost of an e-bike. For public transport, the most usual multiple-trips offers are the t-casual at 1.13€/trip, or for frequent users, t-usual costs 40€/month, assuming two trips per working day, the cost is less than 1€/trip. Finally, for walking, and kick-scooters the cost can be negligible.

[Insert table 10 here]

10. Personal health. Qualitative indicator

We assume that personal health is inversely proportional to physical comfort: higher for active modes, followed by hybrid, then public (supposing one must walk to the stop/station), then

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[11] https://movilidadelectrica.com/analizamos-la-oferta-de-patinetes-electricos-compartidos-de-madrid-empresa-a-empresa/https://forococheselectricos.com/2017/05/ecooltra-llega-madrid-precio-desde-0-24-euros-el-minuto-y-codigo-con-20-minutos-gratis.html#:~:text=eCooltra%20Madrid%3A%20precios,un%20coste%20de%202.4%20euros.

[12] http://www.elpuntavui.cat/territori/article/32448-la-velocitat-mitjana-puja-a-la-ciutat.html

[13] https://www.bicing.barcelona/es/tarifas-

[14] https://www.rankia.com/blog/luz-y-gas/4665223-cuanto-cuesta-recargar-bicicleta-electrica-compensa; https://www.tallerbicicletasmadrid.com/blog/cuanto-cuesta-circular-bicicleta-electrica

private. A justified ranking would see (shared)(e-)bicycles, walking, kick-scooter, (shared)e-scooter, (shared)(e-)motorbikes, then the means with more than 2 wheels.

[Insert table 11 here]

Table 12 offers a simple and synthetic representation of the results presented so far, all at a glance, and figure 4 offers four radar diagrams each one presenting the performance, over the ten indicators of private motorized means, public transport, active mobility and hybrid mobility respectively. Degrowth-desirable options are those that span towards the indicators on the right-hand side of the radar; personal viability is represented by the indicators on the left-hand side of the radar.

[Insert table 12 and figure 4 here]

For a rough interpretation, table 12 can be split into 6 main boxes, highlighted by the double-bordered groups of cells, showing the performance of private, public and active & hybrid groups with respect to the desirable and the viable criteria. This broad view offers the following interpretations:

- There is no typology that appears to be both desirable and highly viable.
- Private means show a strong polarity: not degrowth desirable, they are the most viable (excluding personal health). They constitute a case where benefits are privatized, and costs are socialized.
- Active and hybrid options are opposed to private means, so they also show a certain polarization: they are the most desirable but not totally viable (for comfort and safety, which seems to matter a lot). Their users also suffer injustice in the street which is related to what makes them also unviable: lack of safety, where private means are held responsible. In this case, costs are privatized while benefits are socialized.

- Public transport modes accomplish degrowth desirability, but do not seem much viable in general; certainly, they offer comfort, but the COVID-19 pandemic makes them unsafe. A point for discussion will deal with where the balance should be set between promoting public transport or active and hybrid modes.
- Injustice in the street occurs primarily when different mobility categories share the same infrastructure. When buses and active means share the street with cars, the latter, for their high time-space occupancy and for their high momentum put down potential bus and bicycle users as speed and safety are decreased. In turn, these potential users are likely to switch to private means that are faster than buses and safer than bicycles and a vicious circle is started.

A few more points can be raised from a more detailed interpretation, that looks at specific means and specific criteria:

- Although private are opposed to active and hybrid means, the shared e-motorbike is the least polarized among private options: not undesirable, not much a source of injustice but also less privately viable for being less safe and comfortable. On the other hand, e-bicycles are the most viable within active and hybrid. Shared e-motorbikes and e-bicycles can bridge two otherwise opposed categories. They have been little analyzed because they have developed recently but they surely deserve much more research and policy attention which will be another point of discussion.
- The bus is the exception within public means; it is the most disadvantaged but not for an own limitation: it is for the unjust interaction on the streets with cars. Unless it enjoys dedicated bus lanes, it is slowed down by them, it becomes less viable so that it runs half-empty and its energy efficiency is lowered.
- Within the four car options, carpooling seems to be most degrowth desirable: it promotes a culture of sharing, has a lower space-time occupation, better energy and material efficiency, is less unjust and less polluting. In terms of personal viability, costs are low: freedom might be limited and door-to-door time increased, but trips would also be much cheaper. It is done assuming a

conservative estimate, where average car occupancy doubles from 1.2 to 2.5 passengers. It could be even better if average occupancy were tripled or quadrupled.

- Further, electric cars are not a panacea at all. Considered the ten criteria here analyzed, they are a hoax: not any better than cars as they only reduce part of the local air, noise and heat pollution -but they still emit particulate matter from the wearing out of tires, brakes and engine, their momentum produce noise, and their energy is dissipated into heat. Further, they do not reduce global environmental impacts: they might run fueled with renewable sources -at a large cost in terms of land-use change but which might not appear as bad as climate change. However, they are problematic for what concerns their fuel tanks: e-car batteries require large amounts of cobalt -roughly 100 times more than an e-bike-, whose mining is a source of conflict. A search for "cobalt" in ejatlas.org includes 22 cases; 11 for "lithium" and 25 for "battery".

Our analysis is developed for inner city trips of 5-10 km. For trips of up to 5km, the personal viability of active and hybrid mobility is improved, because travel time and comfort become more bearable, and a further case for enhancing them is made. For metropolitan trips of up to 20km, personal viability would change slightly: private means enjoy further advantage over public options because the frequency and accessibility of the latter decrease. They also gain against active and hybrid means because the latter's comfort and travel time are further reduced. How degrowth of traffic might take place in the peri-urban context is an issue we are dealing with in the discussion section.

In summary, there are no options that are both degrowth-desirable and personally viable. However, the latter is often negatively affected by private means that act against the safety, the comfort, and the speed of desirable options. In the next section we will discuss these findings

Discussion

That public transport should be developed for a transition towards sustainability is a known fact in policy discourses (Miller et al., 2016). However, after having included in the analysis new options only recently appeared in the streets, such as small electric engines and those based on ICT, our results show that active and hybrid options, and those that operate on a sharing/ pooling base need more attention. We observe that while private and self-propelled means are polarized with respect to desirability vs. viability, these new options are more viable and still quite desirable, so that they deserve research and policy attention.

Similarly, that motorized transport is a sector with a high environmental impact is a well-known fact (World Health Organization 2000). However, including other degrowth-relevant criteria such as justice in the street or the public space their infrastructure consumes makes them even less desirable, so that these criteria further feed the sustainability debate.

Not only public: bridging private with active and individual with shared.

E-scooters, e-bicycles, shared e-motorbikes, and carpooling platforms are new options that barely existed a decade ago. The first are blurring the limit between private and active means, for instance e-scooters where the rider is sitting are closer to private motorized means, but they are much lighter, slower, smaller and energy efficient. Sharing and pooling options overcome individual property and use: in Europe web-based apps such as *Blablacar* implicitly hint at conviviality. This progress in new technologies should be welcomed, if it takes users and space away from private means and drives, in theory, towards degrowth principles. More research is missing on the effect of these new mobility options with respect to what was previously employed: are e-scooters making walkers lazy and/or less fit, or are they an incipient transformation in traffic?

From a degrowth perspective, active and hybrid options are also more desirable than public transport: they allow for more autonomy, they require little infrastructure and are, in the long-term,

more financially affordable while having less environmental impact. They are very flexible and adaptable to changing situations: new pedestrian areas or new bike-lanes can easily be realized; instead, strengthening the rail-based network implies a considerable political and technical effort with execution times probably incompatible with the urgency of transformative action. On the other hand, the development of bus services is easy as it simply depends on planning new routes on the already existing streets. It is an advantage for implementing rapid change albeit still too far away for being considered transformative: the real problem rests in first freeing the space occupied by cars and their inefficient use. Policy measures that would foment carpooling, such as congestion charges set at a price high enough so to reach an average of three or more passengers, could reduce cars without reducing car users and would free street space for better uses.

Provided a safe and adequate infrastructure is in place -such as bicycle highways or car-free motorway lanes- e-bikes and e-scooters become viable options for the longer metropolitan trips. Moreover, since COVID-19 the fear in taking public transport must be turned into an opportunity for promoting hybrid mobility which is a good compromise between the viability of private modes and the desirability of public transport.

Addressing injustice in the streets and municipal opportunities for grassroots innovations.

Tackling the unsustainability of urban traffic from a perspective on justice in the streets has the potential to shed better light on a self-amplifying phenomenon: competition for the use of pedestrian and street space is an important source of injustice. If (e-)bicycle and e-kick-scooters users avoid streets for the fear of cars, they might end up riding on footpaths -indeed a fearful action for exposed pedestrians- or switch to seemingly safer modes, including cars. Infrastructure development -which has favored private means- must rapidly reverse towards allocating space for options with lower space-time occupation, such as bike and bus lanes. Second, almost always congested roads are the responsibility of car users which in turn affect the rest of space-efficient

mobility users. Third, traffic is also slowed down by traffic lights, but examples from a car-free China when thousands of citizens moved in autonomy and without the need of traffic lights (Pomerantz, 2002) demonstrate that this form of regulating traffic is due to the large size, mass, and speed of motorized transport. City bypasses and other inner-city highways and tunnels are then built for freeing traffic from intersections and traffic lights. Paradoxically, and a fourth source of injustice, since only private means can benefit from their use, those who are responsible for slowing down transit are then rewarded with access to exclusive speedy infrastructure.

Finally, injustice occurs not only in the streets, but at the urban socio-environmental level at large: the destruction of street life because of roads and cars affects the population at large, with broken neighborhoods and lost opportunities for restoring conviviality back. The potential space that would be freed if cars were absent is extremely large: given their time-space consumption is nine times larger than that of active and hybrid modes, a car-free policy (Crawford, 2000) could imply the reduction of street area to 1/9th of the actual, without increasing congestion. It is beyond the scope of this paper to define how life would be in a city turned 100% car-free or with a 75% reduction in cars. However, concrete possibilities can be envisaged that stem as an opportunity for grassroots municipalism: local administrations own most of the space used for transport infrastructure and could gain back control on it if cars were excluded from it. More dedicated bus lanes for a faster service, more public parks, street pacification for convivial relationships, open air markets and other commercial activities. Since gentrification might occur, new public housing schemes and new buildings for the re-localization of the productive sector could also occupy this freed urban space. Further, seeking car free cities is not a too ambitious goal: the fast development of ICT and COVID-19 have reduced the need to commute, and the boom in co-working spaces can bring work closer to home, within the neighborhood.

Improved urban environmental justice could go hand in hand with short-medium term opportunities to fight COVID-19 by taking space away from cars to increase physical distancing in the open air. For the long-term car-freed spaces are essential for the flourishing of non-capitalist

grassroots activities for transformative social innovation, solidarity economy non-market relationships and a redistribution of paid and unpaid, voluntary working time. Inspired by Bookchin's theory of libertarian municipalism (Biehl, 1998) and the recent rise of new grassroots municipalism (Russell, 2019) the realization of these proposals can democratize, from the bottom-up, local policy-making and the use of public space. Impediments to the right to the city are not only capitalist enclosures (Hodkinson, 2012), but also cars' radical monopoly in the use of open space that, although not fully privatized, cannot be considered as an urban common either.

The COVID19 pandemics has left many world cities empty of tourists and highlighted the vulnerability of this non-productive industry. Degrowth in the urban areas could also take place via the re-localization of productive sectors using dismissed industrial lots as well as the space freed from motorized transport. For instance, the flourishing of productive allotment gardens and similar experiments could combine re-localization of production with environmental benefits; street markets and stalls could be permanently set up, arts and performances. Degrowth is also an invitation to exercise utopian imaginaries (Kallis and March, 2014).

Conclusions

The future of sustainable mobility depends a lot on a balance between viable and desirable options. On one hand, the current excessive preference towards personally viable options in urban traffic undermines social and environmental sustainability. On the other hand, public transport, although desirable, is often not as viable as other means: it depends on long-term investment in costly infrastructure that, as we learn from Illich, cannot be considered as a first-best alternative. Moreover, it cannot contribute as much to the rapid change of mobility patterns that the climate and COVID-19 emergencies require.

By combining a degrowth-based approach with a novel exploration of mobility options that beyond the public vs. private dichotomy includes active, hybrid and shared/pooled means, this paper has offered new insights on how cities can be transformed and quality of life improved.

These novel options score quite well in both viability and desirability criteria: if they could receive the proper policy attention, a positive feedback loop away from private options and towards convivial mobility would be triggered. This would be a step forward towards more convivial cities that are healthier, more just, less polluted, and environmentally damaging.

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