U.PORTO

FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

MEASURING EQUITABLE ACCESS TO PUBLIC TRANSPORT

Analysis of First and Last-mile Shared Mobility Solutions in the City of Porto

JUAN BTESH

Dissertação submetida para satisfação parcial dos requisitos do grau de

MESTRE EM GESTÃO DE MOBILIDADE URBANA

Orientador: Professor Doutor António José Fidalgo do Couto

JULHO DE 2021

MESTRADO EM GESTÃO DE MOBILIDADE URBANA 2020/2021

DEPARTAMENTO DE ENGENHARIA CIVIL

Tel. +351-22-508 1901

Fax +351-22-508 1446

✉ miec@fe.up.pt

Editado por

FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

Rua Dr. Roberto Frias

4200-465 PORTO

Portugal

Tel. +351-22-508 1400

Fax +351-22-508 1440

✉ feup@fe.up.pt

http://www.fe.up.pt

A Inês

RESUMO

A desigualdade no transporte é um problema que precisa ser abordado não apenas por razões éticas, mas também pelos benefícios sociais e econômicos que implica. Níveis mais baixos de desigualdade promovem o bem-estar, a coesão social, a confiança, a segurança e, em última instância, o crescimento econômico. O transporte público acessível, inclusivo e equitativo constrói o caminho para o progresso e desenvolvimento pessoal, permitindo que bairros carentes e seus residentes tenham acesso a oportunidades. No entanto, o acesso equitativo aos sistemas de transporte público não recebe atenção suficiente dos planeadores de transporte, dado que os resultados mostrados em diferentes cidades são fracos. Existe uma oportunidade nos serviços emergentes de micro-mobilidade para melhorar a conectividade das redes de transporte público, completando as viagens de primeira e última milha que podem servir às áreas remotas ou excluídas. A dissertação a seguir tem como objetivo estudar a equidade no acesso aos sistemas de transporte público, considerando as oportunidades desiguais presentes em diferentes grupos sociais através da acessibilidade por proximidade e mobilidade às estações de transporte público. Tem como objetivo explorar diferentes formas de desigualdade, nomeadamente desigualdade geográfica e demográfica, em contraste com a perspetiva tradicional baseada no rendimento. O trabalho começa por uma contextualização teórica que desenvolve as implicações sociais da desigualdade, seguida da aplicação dos conceitos no sector de transporte e mobilidade. Posteriormente, analisa um estudo de caso na cidade do Porto e propõe soluções para consolidar a equidade nos transportes. Os resultados da desigualdade serão medidos no final para avaliar o impacto das políticas em diferentes grupos sociais. Os resultados mostram que as soluções de primeira e última milha na forma de micro-mobilidade partilhada podem melhorar a acessibilidade geral, mas acima de tudo, diminuir a desigualdade. Ao mesmo tempo, melhorar a equidade num sentido (geográfico) pode ter consequências negativas ao ser avaliado desde outro ponto de vista de equidade (demográfico). Para evitar isso, uma estrutura de trabalho focada na equidade com indicadores de desigualdade deve ser adotada no planeamento do transporte, em conjunto com uma forte cooperação público-privada. Um conjunto de diretrizes e melhores práticas é recomendado para alcançar os melhores resultados. Esta análise pode servir como uma linha a seguir para construir um acesso equitativo aos sistemas de transporte público em diferentes cidades e deve ser considerada no desenvolvimento de indicadores para atingir o Objetivo de Desenvolvimento Sustentável 11.2, que se concentra no transporte inclusivo.

PALAVRAS-CHAVE: Equidade, Transporte público, Acessibilidade, Mobilidade partilhada, Mobilidade de última milha.

ABSTRACT

Inequality in transportation is a problem that needs to be tackled not only for ethical reasons but also because of the social and economic benefits it implies. Lower levels of inequality promote well-being, social cohesion, trust, safety and ultimately economic growth. Affordable, inclusive and equitable public transport builds the road for upward economic mobility by allowing deprived neighbourhoods and their residents to access opportunities. However, equitable access to public transport systems is not receiving enough attention from policymakers as poor results are shown across different cities. There is an opportunity in emerging micro-mobility services to improve connectivity to public transport networks by completing the first-mile and last-mile trips which can serve remote or excluded areas. The following dissertation aims to study equity in access to public transport systems by considering the unequal opportunities present in different social groups through accessibility by proximity and mobility to public transport stations. It aims to explore different forms of inequality such as geographic and demographic inequality, in contrast to the traditional income-based perspective. The work is designed with an initial theoretical contextualization with the social implications of inequality, followed by the application of the concepts to transport and mobility. It will then analyse a case study in the city of Porto and propose solutions to consolidate equity in transportation. Inequality results will be measured in the end to evaluate the impact of policies in different social groups. Results show that first-mile and last-mile solutions in the form of shared micromobility can improve overall accessibility, but most importantly, diminish inequality. At the same time, improving equity from one point of view (geographic) may have negative consequences when evaluating through another equity point of view (demographic). To prevent this, an equity-focused framework with measured through inequality indicators should be adopted in transport planning together with a strong public-private cooperation. A set of guidelines and best practices are recommended to achieve best results. This analysis can serve as a guideline for equitable transport planning in different cities and should be considered in developing indicators to achieve Sustainable Development Goal 11.2 which focuses on inclusive transportation.

KEYWORDS: Equity, Public Transport, Accessibility, Shared Mobility, Last-mile Mobility.

TABLE OF CONTENTS

FIGURE INDEX

TABLE INDEX

1
INTRODUCTION

Inequality is a multi-dimensional challenge that can be understood, measured and tackled in different ways. While differences can be naturally inherent to a heterogeneous society with diverse needs and subjective individual preferences, inequality is a growing concern given that it is at its highest level for the past 50 years.[1] This brings an urgent need for policy-makers to embrace this responsibility and occupy their agendas with approaches for undertaking inequality. Development should be profited by everyone and cannot be only targeted at a few privileged sectors. Consequently, the traditional focus of maximizing economic growth needs to shift towards guaranteeing everyone minimum rights.

Transport is arguably considered as a basic human right in modern literature. Transportation allows access to opportunities and freedom of movement and choice. Urbanization with vast opportunities of public transport in metropolitan areas are accentuating inequality, as growth is given only in certain geographical areas, and consequently opportunities are served for those residents. People living in transit deserts, where transportation options are scarce, may have negative effects on their health, job prospects, and economic mobility. This becomes even more important when considering public transport, which should guarantee access to everyone regardless of their social class, economic possibilities, demographic characteristics and disability conditions.

Rather than mobility exclusively, focus should be made in accessibility, which measures the easiness of accessing opportunities, activities or destinations. Poor accessibility is a primary constraint for transport-disadvantaged groups within society. Such groups are often excluded from transport, not because they do not wish nor need to travel, but because their poor accessibility makes travel difficult. Further, and more fundamental, it is not the lack of travel that is the problem *per se*, but rather it is the lack of opportunities that travel represents, such as employment, schools, health care, food supplies, etc. That is, it is not a problem raised by mobility, but by accessibility.

Sustainable Development Goals set an explicit target for providing access to safe, affordable, accessible and sustainable transport systems for all by 2030.[2] This shows a top-level commitment, or direction at the most, to begin to take care of transportation needs from underprivileged social groups. The convenient access to public transport should be broken down by gender, age and monitored for persons with disabilities.

The importance of this research is in first place an ethical reason, based on justice principles and the obligation to guarantee equal rights for everyone. But inequality can also be linked to loss of economic output, greater instability, reduction of trust and safety. Transport planners and policy makers have the

[1] http://www.oecd.org/inequality.htm
[2] SDG (Sustainable Development Goals) Target 11.2, UN 2019

responsibility of working towards closing the inequality gap and guaranteeing minimum levels of accessibility to every sector in society. In this context it is highly relevant and urgent to address this reality.

The rise of shared micromobility in urban areas as first-mile and last-mile solutions is an emerging opportunity to mitigate this problem. These solutions need to be correctly managed and implemented considering the needs of the user. If effectively complemented with public transport through public policies, vehicles could increase area of coverage of metro and train stations for underserved areas.

The following work will discuss on inequality in transport and will propose a framework and best practices to increase accessibility to public transit network through first-mile and last-mile solutions. We will illustrate the concept through a case study in the city of Porto, but learnings and recommendations can be accepted and implemented everywhere, as inequality is present in every society and every location.

2
INEQUALITY

A commonly accepted definition will describe inequality as an unfair situation in society caused by uneven distribution of resources, creating differences in opportunities and outcomes. At the most basic level, inequality describes a state in which parts are not equal. Put within a social setting, differences relate especially with status, rights and opportunities. Differences in these topics are very much at the heart of social justice theories and the concept of fairness and justice are fundamental components that cannot be escaped when thinking about inequality.

People will inevitably have differences in needs and abilities. Travel will have diverse purposes, origins and destinations. Considering the nature of a heterogeneous society and subjective levels of preferences, we can accept a certain level of inherent inequality which cannot be eradicated. Some degree of inequality can impulse creativity and serve as an incentive for progress. But inequality becomes excessive when people are not covering their basic needs for structural reasons such as the place where they live, their age or skin colour, among others.

When political and economic systems adopted that do not promote equality as their main objective, consequences are that some people will be better off and others worse off as a consequence of decisions made. But being in a poor and disadvantaged household, or being from an ethnic minority should not result in having less opportunities than others.

Transport planners and policy makers have the responsibility of working towards closing the inequality gap and guaranteeing minimum levels of accessibility and mobility to every sector in society. Drawing the line in which social differences are acceptable and when they become unfair and urgent to solve, is not an easy task. As mentioned, inequality is inherent to diversity within society, and not every difference in resources will be considered unfair.

However, the limit is clear: differences in rights are not acceptable, and everyone should have guaranteed access to their basic needs. The definition of these needs is what becomes difficult to define, as people have different set of values and priorities. Transport systems are designed as a whole, and not tailor-made for each individual, but we can raise the following questions:

- Is this difference relevant to a person’s life quality?
- Does this difference create a considerable disadvantage in relation to others, in terms of what this person could achieve and its potential for development?
- Is this inequality increasing or decreasing?
- Are transport decisions benefiting society as a whole or only being more advantageous to particular sectors within society?

The described multi-dimensional challenge of solving inequality will be studied through different theoretical approaches that answer these questions and focus on equality as a primary output or goal.

2.1 FUNDAMENTAL PRINCIPLES OF EQUALITY

The concept of fairness and justice is approached from different perspectives in literature about the topic. These are social views and are backed with personal assessments and moral values. This means that other standpoints are equally valid, as long as they have a solid justification. Personally, I will choose the concepts of **egalitarianism** and **sufficientarianism** to argue for decisions in policy-making and proposing social changes. These are closely related to what is most commonly known as **horizontal equity** and **vertical equity**.

2.1.1 MERITOCRACY

Meritocracy is an idealistic political system in which power and opportunities are conferred to people on the basis of talent, effort and achievement. This contrasts to opportunities given by wealth or social class. According to meritocracists, success is a just reward for people's own capacity and efforts, or *merit*. Differences between individuals are well-deserved, as they reflect the effort each individual does to obtain their benefits.

In a more genuine sense, inspired by meritocratic principles, many people believe the hierarchies of wealth, status and power should be organized by this form of evaluation based on achievement. Opportunities should not go to people who have connections or social ranks, but to those best qualified for them, regardless of their background.

Although theoretically this is something we would aim for, given that it is logical to think that people work hard through their merits should have their well-deserved benefits, we also know that it is unrealistic to think that everyone has the same opportunity to develop their own skills and effort and have consequent, equitable results.

2.1.2 UTILITARIANISM

Utilitarianism is an ethical theory that pursues to maximize utility of the affected individuals. Utility can be defined as a property that produces any kind of benefit, advantage, pleasure, good, happiness or even prevents mischief, pain, evil or unhappiness. Hence, the principle will prescribe and justify actions that maximize total utility.

Utilitarianism, an ethical theory within the wider family of consequentialism, will claim that an act is morally right if and only if that act maximizes the good. This is, evaluating the total amount of good for all minus the total amount of bad for all.[3] Fundamentally, this theory focuses on society as a whole and not to the sub-sectors contained, so their specific well-being is not taken into account.

From a strict point of view, utilitarianism is well justified as it maximizes overall output. If we would analyse a before/after situation, following the utilitarian model we would affirm that the policies applied are effective, regardless of inequality. According to utilitarian principles, actions such as public policies should be measured and evaluated through a cost-benefit analysis (CBA). The theory

[3] Stanford Encyclopaedia of Philosophy—http://plato.stanford.edu/entries/consequentialism/

of utilitarianism explained by CBA tells us that we should maximise the sum of benefits for all people. But it fails to specify which people and the degree of benefit that each one of them is obtaining.

For example, a new airport or a faster train will typically be approved if utilitarian principles are followed. It will not contemplate, however, who is benefited from air and train travel. This will be typically the richer groups which travel more and further by plane and train[4], leaving the less-favoured economically excluded from this possibility. So, while overall utility might be incremented, inequality between privileged and unprivileged groups will do as well.

2.1.3 EGALITARIANISM

Egalitarianism is a philosophical perspective that emphasizes equality and equal treatment across gender, religion, age, economic status, and political beliefs. Egalitarianism is traditionally focused on income inequality and wealth distribution, and has shaped various economic and political systems.

Regarding transport, egalitarianism principles are meant to promote equal access and opportunities to everyone involved. This applies to any mode, from walking to car travel, in which everyone should have the same (not more and not less) availability and access to opportunities. Walking, for example, is considered as the most egalitarian mode as it has the less barriers. It is available for almost anyone anywhere, and differences between individuals are negligible. Car travel, on the contrary, is only available to a few privileged. Public transport, the mode we are analysing in this work, is somewhere in between as it can deny access to certain groups because of price, availability, reliability, efficiency, or other. Accessibility to public transport, as we know it, is different for each social group or geographic area. Under egalitarian principles, there should be an equivalent level of accessibility for everyone.

Instead of focusing in policies that optimize utility, such as journey-time savings, egalitarianism focuses on improving equity. Transport policies are justified by improving inequality levels and not through CBA, as in the utilitarianism case. This theory encourages a policy focus on equalising the relative level of accessibility between different social groups. This means, all social groups should have a similar, or equal if possible, level of accessibility.

From such a perspective, the benefits of investing in improving the service level of public transport of a given line to improve the accessibility of an underserved community, such as low-income, geographically excluded, or other sector that shows necessity would be valued more highly than the aggregate journey time savings of the whole population using that line. Hence, egalitarian theories are particularly useful to legitimate policy that aim for equality of accessibility for all sectors of the population.

2.1.4 SUFFICIENTARIANISM

Sufficientarianism is a theory of distributive justice. Having enough opportunities – or sufficient – is a question that is central to determining whether a society is just. This theory focuses on making sure that everyone has enough based on justice principles, instead of being concerned with inequalities between sectors or overall utility.

Sufficientarianism concerns for everyone having enough of some relevant form of advantage. This form of advantage can be constituted of welfare, resources, or capabilities (or something else). While

[4] Banister, 2018.

egalitarian theories focus on differences between people, sufficientarianism assumes that everybody should be well-off up to a certain minimum threshold, which is 'sufficient' for fulfilling their basic needs and to guarantee their continued wellbeing.

'Weak sufficientarianism' suggests it is important to improve the well-being of those people who are below the minimum threshold. 'Strong sufficientarianism' focuses on the degree of well-being of each sector below this minimum. The lower their welfare, the more important is the policy priority. Most sufficientarians agree that equality is not intrinsically valuable and advantage need not be maximized, but only guaranteed to everyone in its minimum level.

In transport, this principle can be applied by determining a minimum threshold of access to public transport. We could aim at, for example, everyone having access to the public transport network within 15-minutes from their homes. Public policies would go in line with sufficientarianism if they worked towards achieving this goal. Once achieved this goal, working towards improving this time to 10 and 5 minutes is not a fundamental objective of sufficientarianism, as basic needs are considered covered.

It is true, though, that there are different criteria to determine what is sufficient and how to measure the minimum threshold. It is even dynamic, and can change over time as conditions improve and what is considered basic becomes more demanding. In any case, the principle is the same, sufficientarianism assesses policies by whether people have enough opportunities, advantages or resources in the outcome of decisions made.

2.1.5 Equality and Equity

The difference between equality and equity must be emphasised. Equality means each individual or group of people is treated equally and given the same resources or opportunities. When authorities allocate resources, the underlying principle is that everyone should have an equal part of it, regardless of their need, circumstances, abilities and preferences. This is considered a fair distribution and actions will be justified by following this principle.

Equity instead, focuses on need. Equity recognizes that each person has different circumstances and allocates resources and opportunities needed to reach an equal outcome. Therefore, equity will typically focus on serving the least advantaged communities. When remediable differences among groups of people are eliminated, we can say we have reached absolute equity.

When social systems are imbalanced, equity is needed to distribute benefits in a just manner. This leads to "fix" systems and creates long-term, sustainable, equitable access for generations to come. Equity focuses on allocating resources to compensate for intrinsic differences in opportunities, and therefore achieve an equal outcome between groups.

Figure 1 Equality and Equity

This difference in treatment is the key to reaching equality, given that even though both promote fairness, but the concept behind is different. Equality treats everyone the same regardless of need, while equity has a stronger justice motor and treats people differently depending on their need. The higher the need, the higher the allocation of resources.

As seen before, sufficientarianism had to define which were the limits and thresholds for minimums accepted. In this sense, equity will need to define which are basic needs and substantive rights, and which are luxuries, as it will only serve the prior, not the latter.

Equity can be shaped in several ways, there are many categories to categorize people and various ways to measure impacts. Transportation equity analysis is important and unavoidable as transport planning decisions often have significant equity impacts but there is no single way to evaluate transport equity. As in this work, it is generally best to consider various perspectives and impacts to achieve social equity within different groups.

Table 1 Examples of Equality and Equity

Examples of Equality	Examples of Equity
Transport subsidies are assigned to the operator, guaranteeing a discount on the fare which benefits all public transport users equally.	Fare discounts on public transports are assigned specifically to students, elders, unemployed and people living in underprivileged areas.
Schedules and frequencies of buses are displayed in English, as this is the language spoken in the country and everyone should be able to speak it.	Schedules and frequencies are displayed in several language for tourists, immigrants and minorities be able to understand it, as well as additional languages for the visually or hearing impaired.
Investments in infrastructure and transport planning are developed to guarantee an equal amount of access per capita, or per square kilometre.	Infrastructure is developed in locations where transport is scarce and people have a greater need to travel to access to opportunities in employment, health and education.

2.1.6 HORIZONTAL AND VERTICAL EQUITY

Horizontal equity is closely linked to the concepts of fairness, described by egalitarianism principles. Individuals and groups are considered equal in ability and in need, and distribution of benefits is assigned equally for everyone. Everyone is treated the same regardless of their background and deserves an equal serve in distribution of resources, benefits and costs. Hence, public policies should avoid favouring one individual or group over others, and result in equal treatment of equals.

Vertical equity relates to sufficientarianism and has a strong perspective from social justice. It accepts the fact that individuals and groups differ in abilities and needs and are advantaged or disadvantaged in any way, such as economically, geographically, demographically, socially, etc. Vertical equity requires that disadvantaged people be identified and given special consideration to ensure that they are not made worse off and that their needs are accommodated. By this definition, public policies are vertically equitable if they favour economically and socially disadvantaged groups in order to compensating for overall inequities. Policies are called progressive if they favour disadvantaged groups and regressive if they harm such groups.

Focus on transportation considers the quality of services between advantaged and disadvantaged groups. Because disadvantaged people tend to drive less and rely on non-automobile modes, anything that increases transportation system diversity and land use accessibility tends to increase vertical equity. This includes walking, cycling, ridesharing, public transportation, taxi, ride hailing, special mobility services, carsharing and micromobility. On the contrary, anything that increases automobile dependency tends to oppose vertical equity objectives by reducing travel options for non-drivers and increasing transportation costs, favouring only those who can afford private cars. As a result, planning and market distortions that favour automobile travel tend to reduce vertical equity, while mobility management and smart growth strategies tend to increase vertical equity by creating more diverse and accessible transport systems.

2.1.7 EQUITY OF OPPORTUNITY AND EQUITY OF OUTCOME

Vertical equity can have limited consensus on how it should be achieved and measured. There is general agreement that everybody deserves “equity of opportunity,” there is less agreement concerning “equity of outcome,” meaning that society ensures that disadvantaged people actually succeed in opportunities available.

Equity of opportunity is concerned with equal access to employment, education, health and transport system, among others. It exists when life outcomes depend only on factors for which persons can control and be considered responsible, and not on inevitable disadvantageous attributes such as circumstances of birth, gender, ethnicity, family background, etc. In practical terms, it means that individuals should be compensated for their disadvantageous circumstances.

Equity of outcome relates to well-being, level of income, educational attainment, health status, nutrition and so on. It has a more traditional view in which income and economic conditions describe people and will be typically evaluated by possession of material wealth or overall living conditions. While equity of opportunity pursues to ensure a common starting place, inequality of outcomes is concerned with the final result and how people use their talents and efforts to exploit these opportunities.

2.2 MEASURING INEQUALITY

Taking into account all the possible ways to interpret equity, there will also be many ways of evaluating and considering variables involved. An equity analysis will depend completely on the nature of the problem, whether it's social, economic, demographical, and the kind of variable measured, whether is quantitative, qualitative, nominal, ordinal, or other. A complete equity analysis will be measured and evaluated from different perspectives to test its robustness. Given this complexity, the most typical indicators are explained below.

2.2.1 COST BENEFIT ANALYSIS

When evaluating public policies and economic decisions, it is very frequent to adopt a cost-benefit analysis (CBA) to analyse the viability and overall impact created to society as a whole. This follows the utilitarianism principles and is the preferred evaluation methodology across all aspects of transport and other decision-making sectors in most countries. The higher the cost-benefit ratio, the better the project or policy.

To measure inequality, this is not the best indicator as it ignores the distribution effects of decisions taken, and how they affect different social groups within society. It measures an overall output, but does not consider the composition of its parts. If policies aim to reduce inequality, CBA does not have the capabilities to evaluate the unequal impacts on subcategories of the population involved.

As opposed to the concept of utilitarianism which will not be adopted to evaluate policies, in this work we will focus on measures that reduce inequality. Increasing overall benefit, or utility, is not the objective of this study, but diminishing the gaps between the most benefited and the least is. Therefore, CBA will not be a central part of our study.

2.2.2 LORENZ CURVE

The Lorenz curve is a cumulative frequency curve that compares the distribution of a specific variable with the uniform line of distribution that represents equality. It typically shows population against a cumulative distribution of income, as inequality is traditionally measured this way, but it can also be compared across other variables. The equality distribution is represented by a diagonal line in which cumulative income equals cumulative population, and the greater the deviation of the Lorenz curve from this line, the greater the inequality.

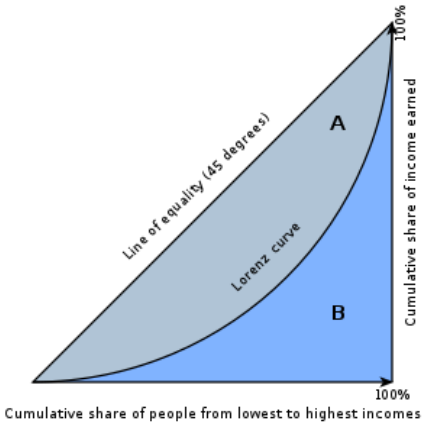


Figure 2 Lorenz Curve

This distribution can be also used for measuring accessibility to transport. The Lorenz curve shows the distribution of total accessibility over the population. It represents the rank-ordered cumulative share of population with accessibility. A point on a Lorenz curve shows the percentage y of total accessibility for the x % of people with the lowest level of accessibility. The line of inequality is described by the diagonal curve of perfect equality. The Lorenz curve shows the deviation from this situation, and therefore inequality in accessibility. The further away from the diagonal, the higher levels of inequality.

2.2.3 Gini Coefficient

The Gini coefficient is a numeric indicator based on the proportion between the Lorenz curve and the absolute equality condition. It is defined as a ratio with values that can vary between 0 and 1: the numerator being the area between the Lorenz curve and the perfect equality line; the denominator being the area represented by the triangle under the perfect equality line. The closest the Gini Coefficient is to 0, the highest the equality condition. The closest to 1 will mean higher levels of inequality.

When measuring inequality in transport, Gini Coefficient will be used to evaluate the equity of accessibility by comparing the ratio of the area between people with accessibility (Lorenz curve) and the line of uniform distribution in which all of the population has perfect accessibility uniformly.

The Gini Score is then an indication of the level of inequality of the accessibility indicator and therefore is related to egalitarianism. It also can include an explicit threshold below which people lack accessibility. Hence, this indicator firmly sustains and represent the underlying ethics principles of egalitarianism and sufficientarianism (or vertical and horizontal equity) as discussed.

Ideally, the Gini Coefficient value should be the closest to 0 as possible. But also, ratios between groups should be equivalent to avoid social exclusion, or groups without accessibility. This means, the distribution of the population cut into any portion should have the same ratio of accessibility. Or in other words, if there is a group of people without access, it should have an equivalent demographic composition as the one that does have accessibility. This will allow to affirm that they are excluded due to random causes and not systematic causes.

However, Gini Coefficient does not measure this kind of comparative inequality between different characterized groups. Strictly speaking, used in this way, the index is only measuring inequality and not social exclusion. It also can throw equal Gini Coefficients to very different Lorenz curves, and fails to evaluate the disparity between the upper and lower percentiles, where inequality is more visible. Therefore, we will have to introduce a new indicator to complement and complete the evaluation.

2.2.4 Palma Ratio and 20:20 Ratio

The Palma ratio focuses better on the top and bottom percentiles, which would represent “the rich and the poor” or in our case, the most privileged with access to public transport, against the least privileged. It is defined as the relation between the top 10% of the population share and the lowest 40% share in the form of a ratio for the subject of analysis.

Palma Ratio addresses the Gini index's over-sensitivity to changes in the middle of the distribution (because of the relation between areas) and insensitivity to changes at the top and bottom, where disparity is the highest. Therefore, reflects more accurately inequality's impacts on society as a whole.

The 20:20 ratio is a similar indicator, with the only difference that it measures the top 20% to the lowest 20%. In the same way, it can be more revealing of the actual impact of inequality in society as it reduces the weight of the middle 60% and gives more relative importance to the extremes of the population. The measure is used in the UN Development Programme Human Development Indicators and many authors believe it correlates well with measures of human development and social stability.

In this work, following the ratio indicators, we will include comparisons between demographic groups to compare initial to final situations. For example, comparing how many elders have accessibility in comparison to how many youths and adults.

2.3 THE IMPORTANCE OF SOLVING INEQUALITY

There is an actual convenience in solving, reducing, or minimizing the undesired effects of inequality. While traditionally transport planners and local authorities would govern through utilitarianism, there is a need to shift this tendency and adopt new principles such as the introduced egalitarianism, sufficientarianism and plan through vertical equity.

When applying policies, evaluation cannot be simply measured by selecting those who will be used by "the most amount of people" and create "the highest number of benefits" regardless of the distribution. These principles are not enough, and an explicit goal of reducing inequality should be set. As we are looking to serve unfavoured communities, it is incorrect to measure results as a total impact on the total amount of people and they should be measured with inequality indicators. In this sense, an extra bus stop that increases accessibility to a disadvantaged area is worth more than another bus stop that serves more people that already have enough accessibility.

But why is it important to plan following equity principles and ignore utilitarianism indicators? Ethical reasons can be enough to justify working towards solving inequality. Unfair differences between people and the injustice created in unequal liberty and opportunities is a reason itself to call for action. Authority's own sense of what is right and what is wrong can be decisive in decision-making. The discomfort created by differences in opportunities for arbitrary reasons can create a motor to plan towards equity.

However, if ethical reasons are not enough, there are more concrete economic, political and social reasons to reduce inequality. Inequality is bad for the economy in general, it has strong negative outcomes on education, social issues, health and stability. Less inequality is associated with higher economic growth.

The system needs a certain degree of equality to function properly and avoid collapsing. Inequality results in the breakdown of trust and cooperation, and instability in general. It can erode social cohesion and increase crime rates. If more people are being excluded from opportunities and at the same time the wealthier or more favoured are exploiting even more and more benefits, the system will inevitably collapse and fail shortly. Social protests, riots and manifestations are almost without exception caused by a sort of inequality or injustice.

Eradicating poverty – not only economical poverty, but also lack of education, health and access to opportunities in general – and rectifying extreme levels of inequality go hand in hand with a country's development. Incorporating new people in the productive system can increase a nation's total output of goods and services, and promote economic growth.

This is especially important to be solved in the transport sector, which represents concrete access to opportunities by mobility and travel. Numerous studies indicate that planning towards equitable urban

environment should include compactness, multi-modality, technology and smart growth development patterns. This promotes social benefits, such as:

- Increase integration, in the sense that poor and racial minorities are less geographically isolated
- Improve economic opportunity, such as disadvantaged people's ability to access education and job opportunities
- Encourage economic mobility, meaning that children born in low-income families are able to become economically successful as adults

Nevertheless, ensuring fairness and equity is not the same as eradicating poverty. As mentioned earlier, absolute equality could create a scenario in which there is no incentive to work and economic growth (measured as in utility for all of the population) decreases. Some income disparities encourage people for economic mobility and the economy keeps working.

Therefore, a sufficientarianism approach should be taken in which interventions improve minimum access to basic rights such as education, health and transportation. This prevents social exclusion and unacceptable differences in opportunities related to basic human needs.

In a more general sense, policy makers should guarantee a situation in which social promotion and economic mobility is possible by assuring sufficient access to opportunities. This creates a scenario in which people are incentivized to obtain benefits according to their efforts – like in the meritocracy ideals – but also guarantees that everyone is able to play this game.

In conclusion, attending inequality pays-off in the long term. Universal access to transport and a fair society are not only about ensuring human dignity, but also about promoting economic growth. These challenges call upon our sense of ethical responsibility and policy-maker duty for creating an overall wellbeing.

3
INEQUALITY IN TRANSPORT

There is little guidance for comprehensive transport equity analysis. Lack of mobility options and transportation challenges adversely affect people's lives by limiting access to basic needs, broader opportunities, and overall quality of life.

The first step to address inequality in transport is to recognize it as an essential good and a basic right. Transportation allows access to opportunities and freedom of movement and choice. Not the transport activity itself – this is, mobility – but accessibility to services and opportunities should be seen as the key objective.

Inequality in transport is seen, for instance, through income. It is the rich that travel more, making long-distance trips using exclusive transport modes such as rail and air, and their levels of mobility are several orders of magnitude greater than the rest of the population.

It is also seen through geographical inequality. Urban areas are better served in public transportation modes, forcing car-dependency in rural areas. Gentrification and increasing income inequality are forcing families to move to neighbourhoods where mass transportation options are scarce, commutes are longer, and daily travel is much more stressful.

Inequality can be given within age groups, as certain transportation modes are thought for certain type of physical conditions which are not common for everyone.

Transport also impose and bear external costs – such as pollution, noise, and other living conditions. Travellers both impose and bear costs, but not equitably between social sectors. Some pay higher costs and use less transport, typically the lower-income groups. The magnitude of inequality is increasing rapidly and the least-fortunate are paying the highest price for transportation faults.

Transport planning often involves trade-offs between economic efficiency objectives (reducing traffic and parking congestion, facility cost savings, accident and pollution emission reductions), which tends to favour transit services on major urban corridors that attract more affluent commuters, and social equity objectives (basic mobility for non-drivers), which tends to favour services used by physically, economically and socially disfavoured groups.

After agreeing that transport is a basic need, then the next step is to aim for equity-oriented policies. In the following chapters we will analyse concrete examples of how inequality is pictured in transport and recommendations to mitigate differences so as to guarantee accessibility to public transport.

3.1 PUBLIC TRANSPORT

3.1.1 CHARACTERISTICS

The nature of public transport is to be an equitable, affordable and inclusive mode of transportation. It is, consequently, on the core of the discussion of this work. Public transport has the characteristic of being subsidized in most of the cases, and therefore it is closely linked with public policies and decision-making. It is through this incentive and other strategies that authorities can impulse equity in transportation and accessibility to basic needs to general public.

Public transport brings wider social benefits through providing better access to services and opportunities to disadvantaged groups and thereby promoting social equity. There should not be any barriers to accessing public transport and price should be affordable and even strongly subsidized to certain cases, when necessary. At the same time, public transport is recognised to be the means for deprived neighbourhoods to access opportunities and therefore it is decisive for upward economic mobility. In a practical sense, we could determine that shorter commuting time is a strong factor in the odds of against escaping poverty.

3.1.2 IMPORTANCE OF PUBLIC TRANSPORT

Almost without exception travelling in public transport modes uses road space more efficiently and produce fewer accidents and emissions than using a private car. Furthermore, underground and other rail-based modes do not require additional road space and therefore do not contribute to road congestion. Moreover, if some drivers could be persuaded to use public transport instead of cars the rest of the car users would benefit from improved levels of service.[5]

Improving public transport accessibility builds the road towards a more equitable society in the sense of reducing private individual vehicles. Cars are proved to be damaging the environment by pollution, apart from creating congestion and noise. Car ownership is naturally exclusive, as there are entry barriers of high purchasing power. Investment of any type that benefits car mode, such as road infrastructure, will benefit unevenly society and thus create more inequality. Noise, congestion, pollution and the space occupied by cars compromise current and future generation's freedom and is therefore unsustainable. Moving away from car-dependency is equitable and promoting and investing in public transport to provide better accessibility is a necessary element of this strategy.

3.1.3 PROFITABILITY IN PUBLIC TRANSPORT

Public transport, as any other business, aims to be profitable. However, it distinguishes from private transport fundamentally in one key item which are subsidies. While private companies need to have a positive balance and show profits to their investors, public transport operators usually rely heavily on provincial and national contributions to continuing operating.

Therefore, by being involved economically, transport planners should be able to respond to public transport objectives and be responsible for their outcome. This brings an opportunity for public transport to be used as a vehicle for social inclusion, provide general access to opportunities and provide efficient mobility that ultimately leads to economic growth.

Creating an equitable scenario will create prosperity and encourage development, as explained previously, so public spending on transport policies to encourage equity are justified in the long term.

[5] Ortúzar and Willumsen, 2011.

Without subsidizing public transport there would be fewer services, particularly where there is social need, for example, in rural areas or at weekends. The purpose of subsidy can be to meet those needs and to provide services that are not commercially viable, for these people to be involved in economic activities.

Public transit planning decisions often involve trade-offs between maximizing **ridership** and **coverage.** The first goal, ridership, responds to profitability. If services are concentrated on the highest demand corridors, more people will use the service creating fare revenue for the operator. The second goal, coverage, is linked to equity. When demand is low and service is dispersed, there is still a need to provide access to worst-connected areas to guarantee social inclusion.

Additionally, and in more contemporary examples, there are ways of subsidizing private forms of mobility – which are also aimed at the general public and inclusive – to lower the fare and make their service more accessible or affordable. This is a hybrid solution in which public-private collaboration provides an efficient an equitable solution for ridership and is explained in better detail in chapter 6.

3.2 Accessibility as an Indicator of Opportunities

Understanding the concept of accessibility and its relation to opportunities through transportation systems will help us describe the inequality picture.

To begin with, the notion of mobility needs to be introduced. **Mobility** is concerned with the amount of travel that any individual undertakes, measured by travel time, travel costs or trips, often divided according to purpose and mode of transport. For example, quantity of kilometres travelled annually by bus by a certain individual or group of people will be an indicator of mobility. Traditionally, mobility is used as an indicator of inequality. Being able to travel more, further, faster, means a larger advantage and more access to opportunities when considering mobility only.

This partially describes an inequality picture but it is incomplete without considering accessibility. **Accessibility** is a wider concept as also it addresses the distribution and availability of different opportunities. The most widely accepted definition of accessibility explains it as the ease to reach opportunities. This refers to the ability to obtain desired services and activities. Having higher level of accessibility will mean higher opportunities, and this is better linked with the described theories of inequality. Similar definitions of accessibility are:

- The potential of opportunities for interaction[6]
- The ease with which any land-use activity can be reached from a location using a particular transport system[7]
- The freedom of individuals to decide whether or not to participate in different activities[8]
- The benefits provided by a transportation/land-use system[9]

Accessibility offers a powerful lens to assess how a mobility system is serving an urban area. We can reframe the efficiency of transport systems in terms of their ability to connect people with

[6] Hansen, 1959.
[7] Dalvi and Martin, 1976.
[8] Burns, 1979.
[9] Ben-Akiva and Lerman, 1979.

opportunities rather than mobility. A city's accessibility level is a product of two variables: (i) the land use patterns of a city, and (ii) the efficiency of the transport system.[10]

3.2.1 Accessibility Components

Accessibility should identify the following items:

1 The **individual** component reflecting the needs and abilities of each person. This includes variables such as age, education level, family composition, etc. as well as the individual's physical condition, income, travel budget, etc. It describes the possibilities of each one to engage with different transport modes, for example being able to drive or borrow/use a car as well as the necessities in surrounding opportunities, for example children needing a primary school.

2 The **proximity** component reflects the land-use system, consisting of the amount quality and spatial distribution of opportunities at destination such as jobs, shops, health, education, green spaces, social and recreational facilities. This will be the opportunities available to which we will desire accessibility. When contrasting with the demand at origin, the result may be competition for activities so each will need to have sufficient scale for serving population needs.

3 The **transportation** component describes how individuals can access to opportunities through transport system, considering different transport modes. This includes the time used, the cost and comfort-related variables. Opportunities can be accessed through transport when they are not given by proximity or the individual has further necessities than what is available. Transport indicators such as travel speed, frequency, availability, reliability, and safety will show the service performance and its effectiveness to access to opportunities in destinations.

In brief, inequality in **accessibility** can relate to the availability of the transport service, the costs of using that service (affordability), and individual constraints (for example, whether someone can drive or whether he or she has a disability). A rich person has greater levels of access to more transport services, can afford to use them at any time, and has a greater potential to overcome any individual constrains.

A broader definition of accessibility refers, not only to physical access to opportunities, but also the transport system itself in terms of its availability (including routing and scheduling), reliability, affordability, safety, and access to information. It also should have accessibility to people with disabilities, hearing or visual impairments, meaning that it should include their specific needs and provide solutions for overcoming barriers. Examples of this are wheelchair access in bus stops and braille language information.

The transport equivalent to the wider literature on inequality is to determine whether accessibility is restricted. This means that the full range of activities that are necessary for well-being and life quality should be available and accessible.

3.2.2 Accessibility Axioms

There are a set of assumptions that serve as a starting point and should be included in any accessibility measure which has common agreement and follows:

[10] Peralta-Quiros, Kerzhner, Avner, 2019.

1. Accessibility varies from one point in space to another, reflecting the importance of the origin in which it is measured. A point can be a map coordinate, a building, a zone centroid or other. People living in denser, central urban areas are more likely to have higher accessibility levels than people who live in low-density and rural areas, since their origin is closer to more activities and opportunities.
2. Accessibility is activity specific, meaning that it needs to have a destination and specific trip purpose. Each activity can have a different accessibility value. A given location may have good access to schools, but poor access to green spaces, for example.
3. Accessibility is a combination of the difficulty in traveling with the attractiveness of opportunities at different locations. This is, the disutility or travel cost in comparison with the number of activities desired.
4. The opportunities over space are aggregated in different ways and weighted by the ease of interaction, typically considering the distance from origin. Opportunities that are closer or easier to access will be typically considered better than those that are further away or more difficult to reach.[11]

3.2.3 Accessibility Limitations

Implicitly, we have assumed that accessibility is a proxy to opportunities, which at the same time represents the social inequality picture. Whilst we believe this is sustained, it does not accurately picture social exclusion, as there are groups that can be systematically excluded and not necessarily taken into account in the overall accessibility levels. If, for example, every municipality has a 90% accessibility level to certain destination, there is no way to know – only by this fact – if the 10% that lacks accessibility is repeated in every case and responds to some kind of minority that is ruled out by the system. Social exclusion is not uniquely described by lack of accessibility, but by a complex set of factors that need to be evaluated with other indicators, as demographic splits like shown in this work.

At the same time, activities or destinations considered in the accessibility analysis might not be suited to the individual's needs. For example, suitable jobs, special care clinics, universities with the right courses, etc. This also happens if the targeted audience does not have the capacity or is unwilling to take advantage of opportunities provided.[12] In our case, we are considering accessibility to public transport network, that is intrinsically aimed at the general population so we will consider it this way and at the same time give a set of recommendations to make sure social exclusion is minimized or completely avoided.

3.2.4 The 15-minute city

The "15-minute city" is a theoretical concept developed by professor Carlos Moreno and adopted by Paris Mayor Anne Hidalgo in recent years. It can be defined as an ideal urban environment in which main activities and opportunities to satisfy human needs are located within a walking or cycling travel distance of 15 minutes. The 15-minute city adapts previous urban theories such as polycentric cities and Transit Oriented Development (TOD) enforcing a sustainability and well-being focus.

[11] Miller, 2018.
[12] Lucas, 2012.

People should be able walk 15 minutes – or cycle 5 minutes – to main destinations desired. This is not a strict threshold but only a guideline, and can be extended to 20 or 30 minutes depending on the type of attraction. For example, a grocery store can be 5 minutes away from home but it is accepted to have a surgery clinic further away.

The 15-minute city is practically automobile-free and public transit is the main non-active mode of transportation – this is, the preferred mode after walking and cycling, which aligns to this work's objectives. Active mobility is used to shape the city's urban form by proximity to attractions and access to public transport stations is considered a basic need.

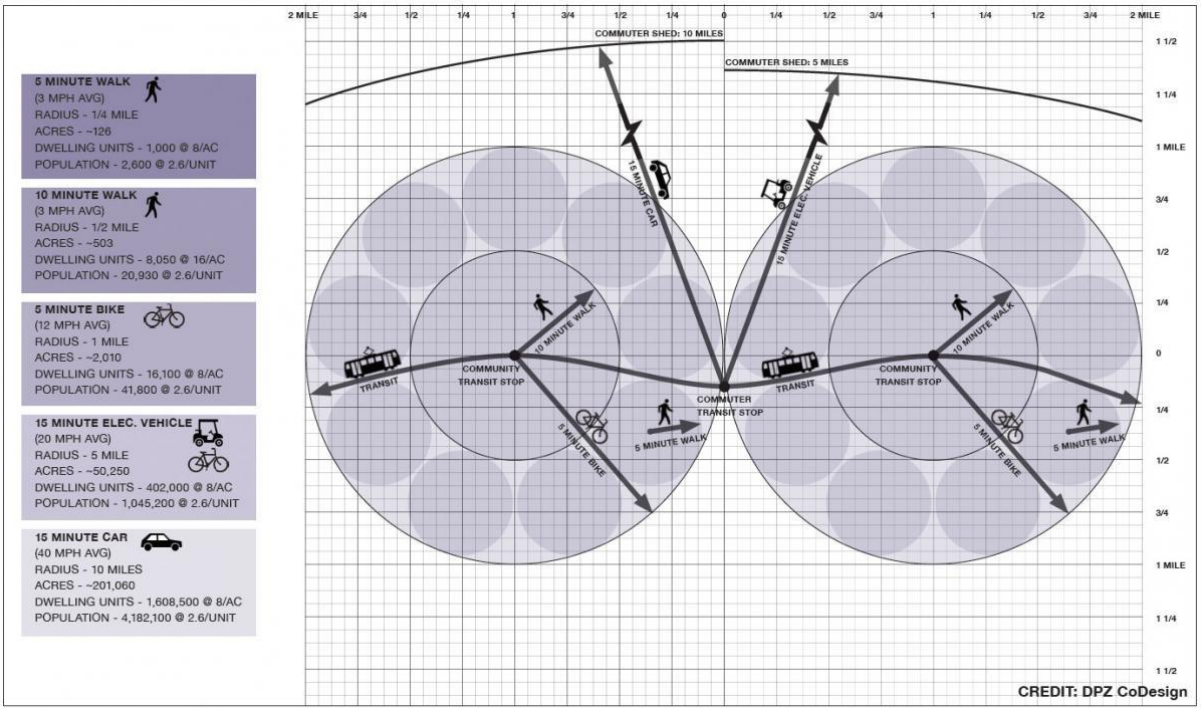


Figure 3 The 15-Minute City

The figure shows how public transport stations need to be incorporated in the 15-minute city. A commuter transit stop is located outside, typically with park-and-ride facilities that serve the commuter shed. A community transit stop is at the centre of the 15-minute city and is accessible walking. This can also be done through micro-mobility vehicles such as e-scooters, (electric) bikes and shared mopeds.

One of the first examples of 15-minute cities was Pontevedra, an 80.000 people city in Spain, which was transformed by Major Miguel Anxo Fernández Lores in the Early 2000s. The historic centre was jammed with cars, congestion, mild pollution and delinquency. It was then converted to a car-free pedestrian area, opening almost 1,700 parking spots for public used and building underground space for cars in the periphery. Traffic lights were replaced with roundabouts to ease traffic flow and diminish noise and air pollution at traffic lights from the gunning of engines. Speed limits were brought down to 30 kilometres an hour, together with the addition of footpaths, bike lanes and green spaces. The result was an UN-Habitat awarded city that can be crossed by foot in 25-minutes and in which children can walk to school alone, streets are alive and filled with people. The city claims zero traffic deaths since 2008, a 70-per-cent reduction in carbon dioxide emissions, 12,000 new inhabitants, a drop in crime and a 30-per-cent increase in business revenues.

Figure 4 Walking distances from main attractions and facilities in Pontevedra

The main principles behind the 15-minute city urban utopia are health, inclusion and safety. The first one because it promotes healthy mobility, short commutes, access to green spaces and reduction in pollution and greenhouse gases. It is inclusive because it is diverse, accessible, affordable, and is built on the foundations of the most equitable mode of transportation which is walking. It is safe because it develops active transport mode infrastructure and discourages car utilization.

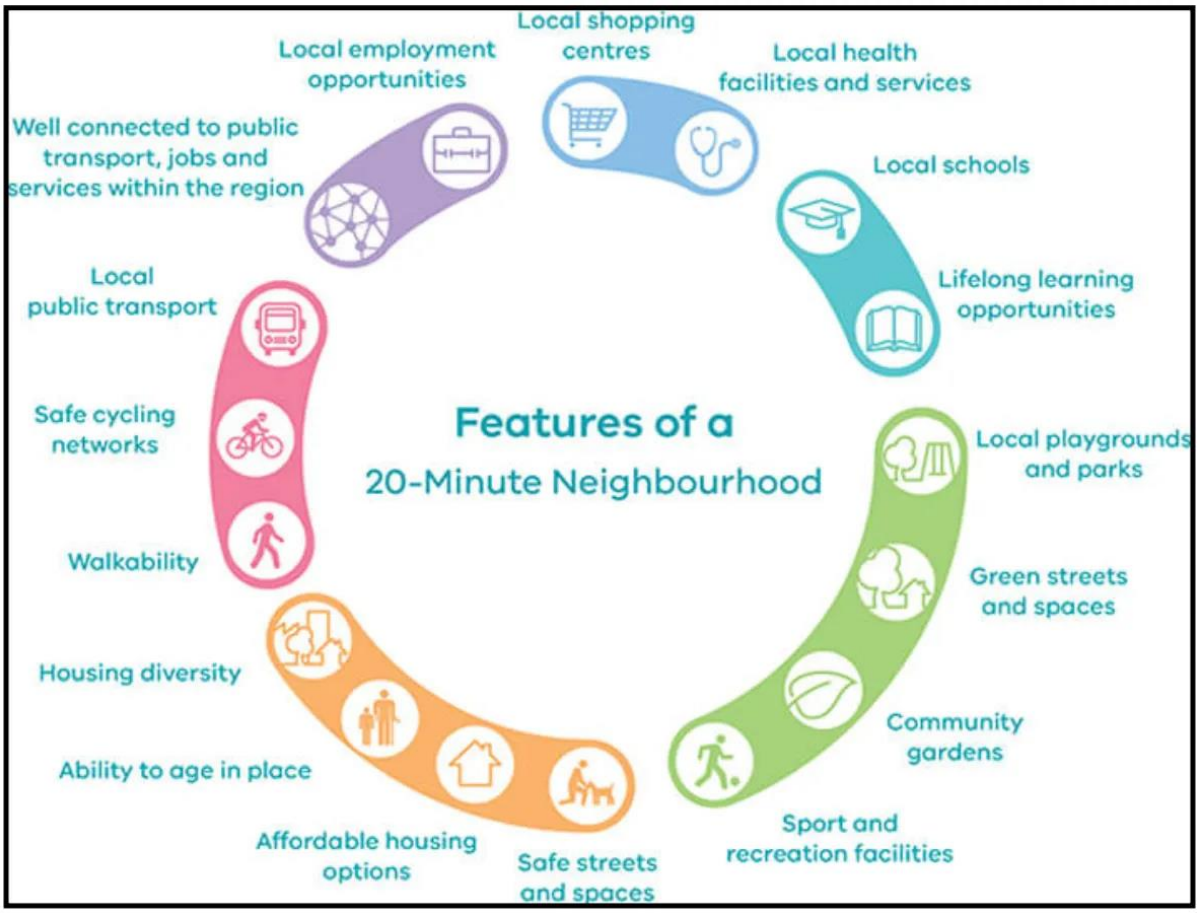


Figure 5 Features of a 15-Minute City

Inevitably, the underlying philosophy at the core of the 15-minute city is equity. Health, inclusion and safety thrive when a society is equitable and there is social cohesion, sufficient basic needs covered and opportunities for growth and development. The 15-minute city encapsules many of the concepts that were explained previously and aligns with the equity-principles endorsed by this work.

3.2.5 Accessibility Approach

In previous chapters we have introduced accessibility concepts and components. What remains to be seen is how it will be approached and considered throughout this work.

Accessibility is employed as a proxy to inequality, as it measures the ease of reaching opportunities and can be comparative of how many people have this benefit and how many do not. In our case, we will measure the ease of accessing the public transport network. This is, as explained throughout this work, because transportation is considered as a basic human right which enables freedom of movement and choice. Public transport, in this sense, should be the preferred choice for an equitable, affordable and inclusive mode of transportation.

Particularly within accessibility to the public transport network, we are choosing the population served by a 15-minute travel time from a train and metro station. The time threshold chosen follows the 15-minute city philosophy, as it promotes equity in healthy, safe and inclusive urban environments. The

transit station represents an interface where a citizen can interact and engage with the public transport network.

If we would like to include further access to opportunities, we would need to evaluate where, when and how the public transport is able to travel. This would consider transportation performance and indicators such as speed, frequency, schedules, vehicle capacity and others. On a broader level, comfort, preference, wheelchair access, information and booking facility could be also considered as accessibility components. However, this exceeds the purpose, scope and origin of this work. As explained before, transportation is a mean to opportunities and can be considered a right, and therefore following a sufficientarianism-based approach, we should guarantee a minimum distance or time in which the public transport network should be available.

Limitations of this type of approach are that it does not measure directly well-being and it does not consider individual preferences. However, different needs will always be present in heterogeneous groups of people. To counter this effect, we will also analyse demographic accessibility splitting population by age and gender.

3.3 Fundamental Principles Adopted

After introducing theoretical background in the previous chapters, the fundamental principles will be put into practice in the transportation sector and later in a case study.

The utilitarianism principles and the Cost Benefit Analysis will not be considered, as we are not looking to maximize overall benefit, but to decrease inequality between social groups affected by transport policies.

We cannot entirely sustain the meritocracy principles either. Inherited conditions at the moment of birth, such as income level, gender, or geographical birthplace create inexorably inequality in freedom of choice. This is seen, for instance, when comparing geographical inequality and the capabilities of choosing where to live. Living closer to the public transport network will guarantee higher accessibility, but this is associated with higher housing prices, therefore available for people with higher wealth and income possibilities.

However, making sure everyone has the same opportunities and that there are no significant advantages on the starting line would mean pushing for merit. If everyone has the minimum opportunities fulfilled, possibilities for personal development can be seized. This philosophy agrees with the fundamental principles of egalitarianism (or horizontal equity) and sufficientarianism (or vertical equity) as explained before and should be adopted as principles in transport planning.

Concretely, objectives are focused on equal accessibility levels as an approach to opportunities and minimum travel time to public transport stations. While inequality is inherent to transport and social systems, we aim at mitigating it through sufficientarianism and egalitarianism principles and policies based on vertical equity.

3.3.1 Planning through Egalitarianism

Egalitarianism is considered when aiming for equal accessibility for every zone. For example, when aiming at reducing geographical inequality, we should aim that every neighbourhood or subsection within a city has equal levels of accessibility. As there is no point in reducing accessibility levels to

zones, as it would be expensive and inefficient, we will ask that every area has the same level as the highest one. This will guarantee equality as differences within each zone are minimized.

This principle responds to equality in service distribution as each will have an equal level of public service (in this case, accessibility to public transportation system). This applies specifically for civil parishes, in which we intend for all of them to have equal accessibility. The measurement used for egalitarianism will be the Gini-index, which varies between 0 and 1, with lower coefficients meaning more egalitarian scenarios.

3.3.2 Planning through Sufficientarianism

Creating an equal scenario within geographic areas is a must, but it does not consider the actual level of accessibility. Therefore, we need to set a minimum threshold to determine which we consider sufficient. This will be considered in the form "at least one public transport station within 15 minutes travel time" and responds to sufficientarianism principles. This is a hard condition, and a minimum accepted value for accessibility to destinations. The measure of sufficientarianism is described by the slope of the Lorenz curve up to the threshold value, which is the minimum accepted. The concept of sufficientarianism therefore provides an ethical justification for developing policies that provide a minimum threshold level of accessibility to public transport stations.

3.3.3 Planning through Vertical Equity

Vertical equity approach will focus on the resources allocated to guarantee equal opportunities. In the case study, different vehicles are provided to each area according to their need, specifically the distance to the stations. To achieve the 15-minute goal of accessibility, policies are executed according to the necessity of each sector considered. This is the core of vertical equity, which exceeds the principle of treating everyone equally and promotes distribute justice by taking into account the needs and abilities of each individual or social group to promote equality.

Vertical equity initially differentiates each group according to their needs, and is progressive with respect of the inequality factor. The more disadvantaged you are, the better the benefit you will receive. It is also focused entirely on needs and not on luxuries.

It is only right and fair that the benefits of those decisions (public investment, spending, infrastructure) are spread across all sections of society, and we support that the less well-off should benefit disproportionately, suggesting that they should have more to gain from increasing opportunities.

In this case, service distribution is according to need: to each a share of public expenditure or service based on need, as government has chosen to define it and taken steps to ameliorate it. We use different vehicles to have a different spatial coverage within this 15-minutes and achieve these goals.

3.3.4 Combination of Principles

The adopted principles of sufficientarianism and egalitarianism should complement each other and not compete. Sufficientarianism provides a limit. If this is surpassed, we still follow egality in which everyone should be treated as an equal. This serves as a double effect policy in which inequality is tackled from different angles. This applies as well to the concepts of horizontal and vertical equity. The use of multiple indicators that respond to equitable principles will guarantee the principles are successful and robust.

Through vertical equity we intend to minimize disparities between the lowest and highest groups[13] with a utilitarian benefit of maximizing average accessibility. Sufficientarianism will provide a minimum standard of accessibility for transportation equity analysis.[14]

Equality in opportunity, and not in outcome, should be measured as it represents the freedom of choosing and guarantees an equal starting point for everyone. At the same time, we want to move away from income and wealth traditional points of view, a typical measurement of output. Equalizing income itself should not be the main objective, given that not all people convert income into well-being and freedom in the same way. In practice, equality of opportunity exists when policies compensate the individuals facing disadvantageous circumstances.

Finally, it is worth mentioning that limits vary along with progress. If general improvements in technology and standards of living are widespread, we will aim at a higher minimum level when considering sufficientarianism in planning. At the same time, distribution of resources is a dynamic process and social exclusion can change from time to time. Today's disfavoured groups can be those privileged tomorrow. Therefore, planning for equity should be a continuous process entrenched in public policy.

[13] Martens, Golub and Robinson, 2012.
[14] Titheridge, et al, 2014.

4

GAPS IN THE STATE-OF-THE-ART

The state-of-the-art analysis explores the current state of development of the equity-focused transport planning field. Bias & distortions that need to be solved can be found below together with the opportunities of improvement.

4.1 BIAS & DISTORTIONS

4.1.1 MOBILITY VS ACCESSIBILITY

Traditionally, mobility was the only indicator used to evaluate inequality. People travelling more or travelling less will be seen as advantaged or disadvantaged. However, we've described how mobility levels do not necessarily reflect high accessibility levels, and most concretely, high access to opportunities. Measuring inequality through mobility gives an incomplete picture and it can be improved by measuring accessibility levels. Mobility is not an end by itself, and the ultimate goal for transport should be accessibility, which refers to people's individuals to reach desired activities.

At the same time, a mobility approach undervalues the importance of land use policies to increase accessibility. Urban density, diverse land use, polycentric cities, transit-oriented development, walking infrastructure and human-centred built environment are subjects that can improve accessibility without implying more mobility.

Improvements should be valued based on the number of public services and jobs accessible to people considering all transport modes, not simply travel time savings to vehicle travellers. Non-automobile modes (walking, cycling, public transit) should be part of the discussion, as well as land use and urban to improve accessibility and achieve transport planning objectives.

Table 2 Mobility vs Accessibility

Mobility vs Accessibility based transport planning[15]	Mobility	Accessibility
Definition of Transportation	Vehicle travel	Ability to obtain desired services and activities
Measurement units	Vehicle-miles/kms	Trips, generalized costs
Modes considered	Automobile, truck and transit	Active transport (walking and cycling), motorized, mobility substitutes
Common indicators	Vehicle traffic speeds, roadway Level of Service, costs per vehicle-mile	Quality of available transport options, average trip distances, costs per trip
Favoured transportation improvement strategies	Roadway and parking facility expansion	Improvements to various modes, transport demand management, smart growth development policies

Accessibility-based analysis provides a more accurate range of impacts and options considered in planning. It recognizes the important roles that active modes public transport, and alternative modes of transportation can play in an efficient and equitable transport system, as well as considers impacts of urban sprawl, land use and compacity on accessibility. This provides more comprehensive equity evaluation.

4.1.2 Inequality as Income

Inequality will be typically measured in income or in wealth. As analysed in this work, inequality goes beyond income and adopts other forms, so it needs to be treated holistically and not only focusing on one output indicator, but evaluating it across all levels. Consequently, it is recommended to explore socio-economic, demographic and location variables among others that can be relevant in the way they affect people's lives.

Gentrification, ghettoization, socio-spatial segregation are phenomena that go beyond income and reflect the well-known benefits of living in urban areas. This analysis requires a more contemporary approach using indicators that evaluate geographic inequality. At the same time, the age gap, gender gap, racial gap and other social issues need to be evaluated through demographic information, evaluating inequality between different minorities. Inequality should be measured all of its possible forms to truly evaluate an equitable society.

4.1.3 Lack of Equity Objectives

Current planning practices are biased and distorted in ways that are both horizontally inequitable (they favour some users over others), and vertically inequitable (they tend to harm disadvantaged people). Transport models tend to generate suggestions for transport improvements that benefit highly mobile population groups at the expense of the mobility-poor.

[15] Litman, 2003.

Traditional utilitarian view and the cost-benefit analysis will miss the inequality picture. Given that overall utility is typically the number one objective in policy-making, inequality reduction rarely gets to be included in decision making.

For example, when tendering licences for micro-mobility operators, there are not many cases in which accessibility objectives have to be achieved, and it is rarely seen that cities demand operators to distribute vehicles in underserved areas. E-scooters and bikes will result being deployed in the city centre, or touristic and wealthy areas where ridership is higher and more profits can be obtained. Basing transport policies on the distributive principle rather than demand exclusively would secure a minimum level of transport service for all population groups.

Equitable transportation should support multi-modal options, affordable, sustainable, reliable, efficient, safe and easy to use. Quality transportation services should be accessible to everyone to reach destinations, independently if needed. Transport planning processes should engage communities and incorporate them in decision-making to avoid underrepresented minorities.

4.1.4 Scarce Public-Private partnerships

There is current lack or scarce cooperation between private companies and authorities to achieve equity goals. Specifically, this respects to micro-mobility operators and city municipalities.

The rapid propagation of shared mobility services represents a significant opportunity for the public sector to partner with new private operators to increase and expand more equitable and sustainable transportation alternatives in cities. But there is also an opportunity to serve historically disfavoured communities by making transportation affordable and available, if public-private cooperation exists.

Cooperation can be given in spatial coverage, data-sharing, flexible schedules, capacity management and many other operational matters that can achieve higher efficiency and equity. This needs to have clear equity goals from the public side, with distribution rules, network access regulations and incentives to encourage operators achieve them, and finally metrics and indicators to understand progress. Cooperation between public and private sector will help create an equitable environment in which the less favoured groups of society can increase their accessibility and mobility levels.

4.1.5 Profitability in Transport

Fundamentally, shared micro-mobility operators are commercial businesses, which have profit goals to achieve and a set of financial challenges to affront. If micro-mobility operators are to be seen as first-mile and last-mile solutions to complement with public transport, then we should not expect them to have profit as the only goal and they should not be seen as a lucrative source of revenue for the city.

On the one hand, mobility operators need to profit and show results to their venture capital (VC) held firms. On the other hand, cities need to provide transportation services that are affordable, safe, equitable, and ubiquitous, even if it is not profitable. Consequently, even though there are some exceptions, the general case is that classic public transport does not make a profit. Thus, expecting shared micro-mobility operators to comply with equity goals while making profit is unrealistic. If vehicles are going to be privately owned, such as the case is for the time being, economic incentives should be granted by local authorities to make their business feasible while achieving public goals.

4.1.6 SUBSIDIES

Traditional subsidy allocation is based on mobility, not accessibility. Miles travelled, passengers taken, time spent in vehicle are indicators of mobility that would commonly argue to deserve a national contribution for operation to be profitable. However, accessibility is rarely considered and the destinations reached and opportunities available are not indicators that appear in the subsidizing conversation.

At the same time, subsidies are given to services and rarely to users. The most common case is for operators to receive a public monetary contribution that makes their fare more affordable – but affordable for everyone equally. This is a horizontal equity policy and does not take into account the difference in economic needs by the users. Applying subsidies directly to users according to their need of accessibility and their financial condition would be a vertical equity strategy. These can be allocated by geographic areas, individual income, abilities, physical disadvantages, etc.

Finally, subsidies to new forms of mobility – such as first-mile and last-mile, micro-mobility and others – are not as frequent as subsidies to public transport. Specifically, train, car, and air travel are heavily subsidized which are more exclusive and aimed at people with higher purchasing power. New forms of mobility are not seen as public transport and there is a big opportunity in adapting their scheme to complement with buses, trams, metros and trains.

4.1.7 CAR-DEPENDENCY FOCUS

Transport planning has favoured individual, privately-owned modes of transportation throughout the XX century and the legacy has prevailed. Car-dependant policies fail to acknowledge active and equitable modes of transportation such as walking and cycling as well as neglecting public transportation benefits.

Car-based planning tends to favour faster modes and longer trips over slower modes and shorter trips, and therefore motorists over non-drivers, which has unequitable results. This goes hand in hand with more funding and subsidies for roadway and parking facilities than other kind of investment in infrastructure.

Charged parking, congestion pricing, road pricing, High occupancy vehicle (HOV) lanes, carbon taxes, are only some of the new public policies that are being incorporated in major cities that help decrease vehicle ownership and utilization, develop other modes of transportation and move away from the car-dependency bias.

4.1.8 IMPACT MEASURING

Making progress towards equity goals requires standard metrics that are easily monitored and regularly evaluated. These are virtually non-existent at the time being, while private shared mobility services are rapidly expanding their operations in more and more cities. As previously identified, equity objectives should be incorporated in transport planning to identify gaps, develop effective strategies, and subsequently measure progress.

At the same time, conventional economic evaluation does not consider the entire indirect costs of roadway capacity expansion (such as greenhouse gases emission, noise pollution, fatality rates, social exclusion, physical segregation, etc.) and overlooks the full benefits of alternative modes of transportation (such as health benefits, equitable transportation, cleaner urban environment, safety,

etc.). This gives an incomplete evaluation which fails to measure properly the impact of transport decisions.

The value assigned to accessibility gains should be inversely related to people's current levels of accessibility to reflect diminishing marginal benefits, so accessibility gains for the mobility-poor (lower annual miles travellers) should be valued more than for mobility-rich (high annual mile travellers), because accessibility-constrained people tend to benefit more from improved transport. Travel time savings for mobility-poor people should be valued higher than for the mobility-rich to achieve consumer welfare and efficiency, as well as social justice objectives, for example, by allowing disadvantaged people access education and employment that increases their productivity.[16]

4.1.9 LEGISLATION

As new forms of mobility rise, game rules need to be set to cover the grey areas in legislation. E-bikes and e-scooters are many times not recognized in the legal norm of vehicles. They are not meant to travel in the sidewalk but also are very dangerous to be used on roads with other type of motorized traffic. To comply with law, a specific usage has to be described together with maximum speeds, safety equipment (i.e., helmets) and a driving license if necessary.

4.1.10 INFRASTRUCTURE

On the same line as the previous point, there is a huge infrastructure gap when considering micro-mobility. Bike-lanes and parking infrastructure should be built by local authorities to incentive first-mile and last-mile shared mobility but also guarantee safe and equitable ridership.

4.1.11 CUSTOMER NEEDS

Micro-mobility services and other first-mile and last-mile solutions have designs that become restrictive in the way they can be used. Small wheels, maximum weight capacity, the need to maintain balance, and the non-adjustable components are some of the items that make e-scooters and e-bikes not suitable for everyone, and therefore inequitable.

Apart from the design component, there are other customer needs unattended. Access to technology is limited not only because of the age gap but also because of access to smartphone and devices to unlock vehicles. Accounts usually require to register, accept privacy and data transfer policies which create barriers for utilization.

Platform access requirements focus on reducing unseen barriers for disadvantaged users. These requirements move beyond distribution to encourage cash payment options, access for those without a smartphone, community outreach, and low-income passes.

4.1.12 PAYMENT OPTIONS

Apart from the usability obstacles, many transport services require having a bank account or debit/credit cards. Micromobility services do not take cash and may require targeted education on how

[16] Litman, 2019.

to get an account established. This usually prevents low-income sectors to being able to access to this mode.

The case for public transport is different, as it is almost universally paid with a pre-paid card or with cash and coins onboard of the vehicle. This is, as we know, accessible for everyone. Merging payment options and extending the transport card possibilities to include new mobility forms will have a greater penetration in financially excluded groups. This also sends a strong message of what the new mobility forms are meant to be. First and last-mile trips should be considered as part of one's total journey. Single-pricing multi-modal trips will build a stronger, wider and more efficient public transport network.

4.2 OPPORTUNITIES

4.2.1 SDG OBJECTIVES

There is a strong orientation from the United Nations (UN) and particularly the European Union (EU) to develop equity in transportation. Sustainable Development Goal (SDG) 11.2 states an objective of reaching by 2030 "access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older".[17]

As noticed, there is an intention to allocate efforts towards accessibility, investment in public transport and attending the special needs of minorities, with a vertical equity perspective.

4.2.2 DATA SHARING

Developing policies to incentivize the equitable placement of vehicles is becoming easier to monitor and reward. Through emerging data-sharing requirements that are part of new mobility operating permits, cities can access new data to evaluate the availability and use of services such as shared bikes, scooters, and cars in traditionally underserved areas. This presents an opportunity to control scooter and bike location and enforce if necessary. New mobility solutions can help cities make progress towards transportation equity goals - if cities partner with them and can evaluate progress with data.

4.2.3 SHARED MICRO-MOBILITY

The emergence of micromobility is a recent tendency in urban mobility which has been launched mainly by hypergrowth private start-ups. It is an underexplored tool to reduce inequality as it provides a new opportunity to address underserved communities.

The shared vehicles used in first and last-mile trips commonly include e-scooters, bikes and e-bikes. Micro-mobility becomes a new way for a city to offer publicly accessible mobility if they intend to supply and own the vehicles. But even in the case of private micromobility, vehicles require access to the public right-of-way so cities have the authority to permit and regulate their use.

The rapid adoption of these services indicates a clear market demand, yet, without government incentives or regulations, they tend to serve areas with robust transportation offerings, while continuing to leave the underserved edges vacant. The most popular locations for micromobility are

[17] United Nations, 2015.

often locations that are already well served by public transportation options such as metro and buses, and have also good accessibility by proximity.

A possible approach for equitable micro-mobility is to mandate a percentage distribution in certain zones, such as communities of concern, low-income areas, or other priority zones for transit service delivery. The second approach is more market-driven, using fee incentives to operators. A third approach can be allowing more vehicles to the licenses given if meeting certain conditions.

Tenders in cities can have scores depending on different criteria to achieve equity. Some proposals tend to include strategies to ensure that low-income residents are aware of services and how to participate. The operator can also have an approach to providing service to low-income residents including diverse payment options and fare discounts to reduce barriers to participation.

4.2.4 Densification and Increasing Urbanization

Increasing urbanization and densification brings more people to cities. Micro-mobility becomes more cost-efficient in denser areas as more people can be benefited per vehicle implemented. While small cities become medium and large cities, transportation needs to be thought through to be equitable geographically across all zones. Where public transport is not able to reach and offer their services, alternative mobility solutions need to be available.

5
ANALYSIS AND CASE STUDY

In this section, we will put into practice the theoretical concepts explained in the previous chapters. The transport inequality phenomenon will be studied as a practical case study in the city of Porto. Geographical and demographical inequality in terms of accessibility will be measured and later on, solutions and recommendations will be presented.

To begin with, accessibility will be measured to public transport stations, specifically metro and train. By determining percentages of populations that have access to each of these transit systems in each civil parish of the city, we will capture geographic inequality. The initial objective set is the following:

All civil parishes should have 100% of their population with at least 15-minute accessibility to a public transport station.

The explanation of this concept reflects the principles explained previously in the following way:

- **Accessibility**: Used as a proxy to equality, it measures the easiness of reaching opportunities.
- **Public transport**: Presented as a driver of accessing to destinations. It is the transport mode intended to be affordable, inclusive and equitable.
- **15-minute city**: This time threshold is being used as it represents the 15-minute city principles of equity, safety and health.
- **Social inclusion**: The objective states that 100% of the population should have accessibility. This objective might seem ambitious, but a lower goal cannot be considered given that if 90% was aimed, for example, there might be a 10% that is systematically and structurally excluded from accessibility for being part of a social group, which would reflect inequality.
- **Sufficientarianism**: A minimum limit is set of at least 1 station within 15 minutes travelling time. There might be more stations within this threshold, but we are only focusing on providing the sufficient resources considered to guarantee equal opportunities.
- **Egalitarianism**: All civil parishes are treated equally, there is no differentiation within them and the objective is set for all of them.
- **Vertical Equity**: Resources will be allocated to those people living in civil parishes with the larger need, or which have lower values of accessibility, to meet the proposed goal.

The objective will serve as a strong guideline to aim and measure equity. We will study an initial situation for geographic inequality and after recommending solutions, an improved situation will be presented. The Gini coefficient will be used as a numerical indicator, and the Lorenz curve to visually represent the disparity in geographic inequality.

An equity analysis per mode is given later, which evaluates which of these modes is more accessible, whether it is the train or the metro, and which has a greater degree of equity.

After the geographical evaluation, we will proceed to study the case of demographic equality and how the implemented policies affected this scenario measuring a before/after situation. We will use ratios to compare accessibility levels between different social groups, such as age groups. Finally, a set of best practices for policy-making and recommendations to increase accessibility while being inclusive for all social groups are described.

While this analysis uses the city of Porto as an example to put in practice the theoretical concepts, it can and should be applied to any city in consideration. Software used to measure degrees of inequality will be QGIS, a geospatial GIS tool.

5.1 SCOPE

This dissertation, even though it has a strong social component, surges from an engineering degree. Therefore, it intends to study behaviour and network design of public transport and propose technical solutions from the supply side. It will be narrowed to transport, not to inequality as a whole.

We chose the train and metro *stations*, but can be applied to bus stops, metro lines, or other elements such as parks, hospitals, schools, more related to urbanism than transport. Any other destination.

When considering accessibility to public transportation, we will pick exclusively metro and train stations. Bus lines will not be considered, not only because it escapes the complexity and scope of this work, but because of the difference in nature of this transportation mode. Buses can have flexible stops and routes. This can be modified as pleased, and do not require first-mile or last-mile solutions to complement them. Instead, metro and train stations are fixed to one location that serves a delimited area, so delivering equity is more challenging from this point of view and alternative solutions have to be explored.

When considering access to stations, we will accept as enough 1 station. This symbolically and practically represents people's access to the transport network and all the benefits this implies. If we considered more than 1 station, we would have to measure inequality to each number of stations, by transport mode, split into each demographic group, by area, and by each level of accessibility in consideration. This adds an unnecessary complexity which will difficult the understanding of the work. Additionally, it can be redundant if the stations are from the same metro or train line and do not provide extra accessibility, which is something very common in practice.

It is also important to highlight that we will not measure the transportation mode quality or efficiency. This would include frequency, speed, route, comfort, availability, information, price, payment options and other variables that add an extra layer of complexity and do not fit in this work's objectives. As mentioned, accessibility to transportation network will be considered sufficient.

Inequality will be measured in 2 main ways. First of all, geographically, this is, within civil parishes. People living in certain area will suffer from more or less accessibility and this can be effectively represented in a map. The second type will be demographically, specifically within age groups. The accessibility to elder in relation to children and other age groups will be analysed to assess if there are differences in opportunities and allocation of resources. As older individuals age out of driving, they still have the interest and means to move. We want to know what policy gaps can be tackled to seize this opportunity.

Income inequality will not be evaluated, as we intend to explore alternative ways of inequality, less studied in the state-of-the-art. However, we need to understand there is a correlation between income and for example, area where people lived which relates to house pricing. Houses with more availability of opportunities will usually be more expensive and therefore more available to rich people. Rural communities face physical isolation, limited economic diversity, higher poverty rates and reduced access to core services like healthcare and education.

Finally, the case study will focus on the area of Great Porto. This is an urban area with a suburban periphery where first and last mile solutions could serve for accessibility. The reader should be able to put in practice the theory explained and aim to reduce inequality in transport accessibility in any city or area studied. Different variables can be considered and groups can be compared in different ways, following the reader's own interpretation and based on the principles of egalitarianism, sufficientarianism and vertical equity.

5.2 Application of Method

Through software QGIS, we initially map the network of train and metro stations provided by Metro do Porto and CP (Comboios de Portugal). A shapefile is provided in which each dot represents a station, either metro (blue) or train (green).

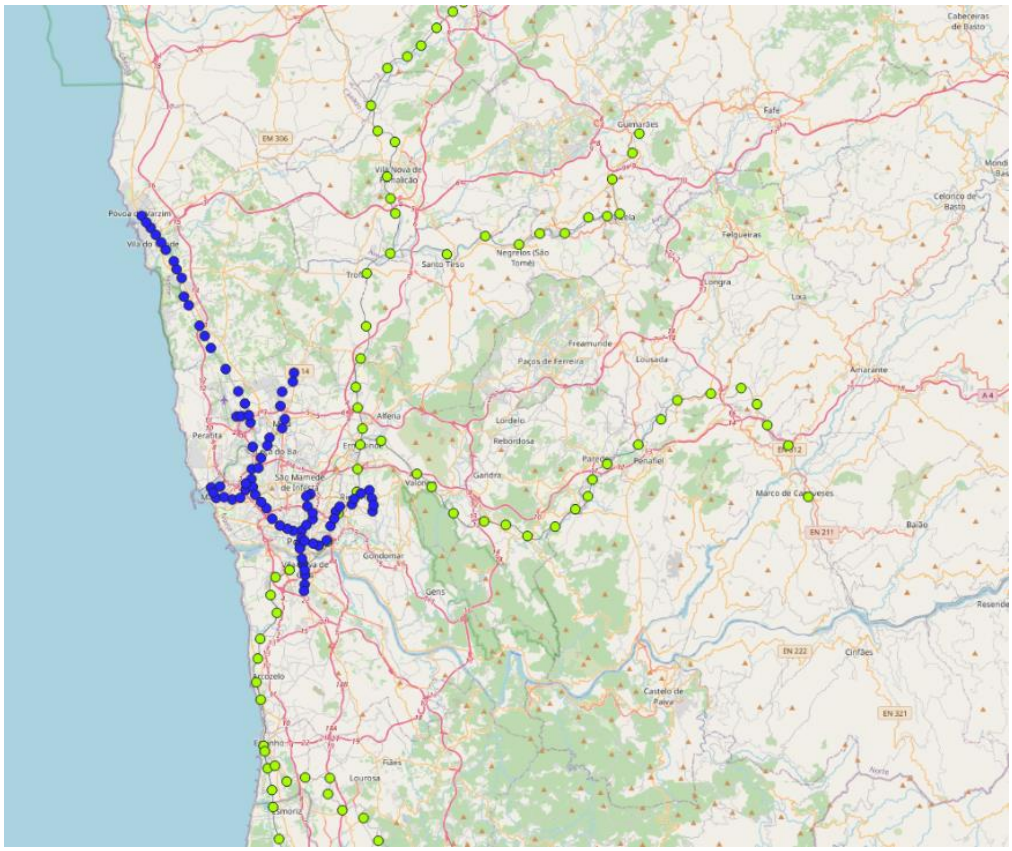


Figure 6 Metro and Train Stations in Porto

The demographic information in comes in form of a .csv file provided by INE (Instituto Nacional de Estadísticas). Grouped by the following, in decreasing order from larger to smaller:

1. Concelhos (councils)
2. Freguesias (civil parishes)
3. Secções (sections)
4. Subsecções (subsections)

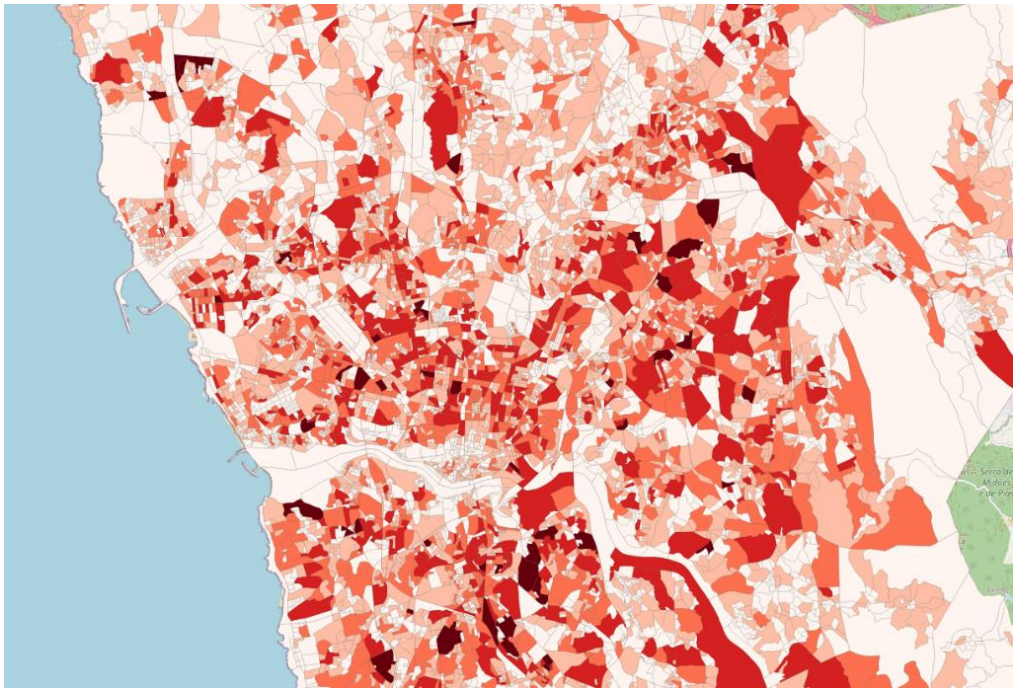


Figure 7 Population Distribution in Porto

The map shows subsections color-coded by population. A rigorous data check has to be performed in order to eliminate errors and complete missing information. Demographic information and population density.

Next, isochrones are drawn from each station. Isochrones measure destinations accessible within equal amount of time from an origin. In this case, as we are using the plugin from ORS Tools, we will consider the actual infrastructure of the city and a walking distance of 4 km/h to calculate the areas of these isochrone. Inspired by the 15-minute city concept, the initial baseline of accessibility will be of 1000m which is the walking distance that can be done in 15 minutes. We will later also consider isodistances of 3000m, 5000m and 10000m intended to represent 15-minute travel in different transport modes.

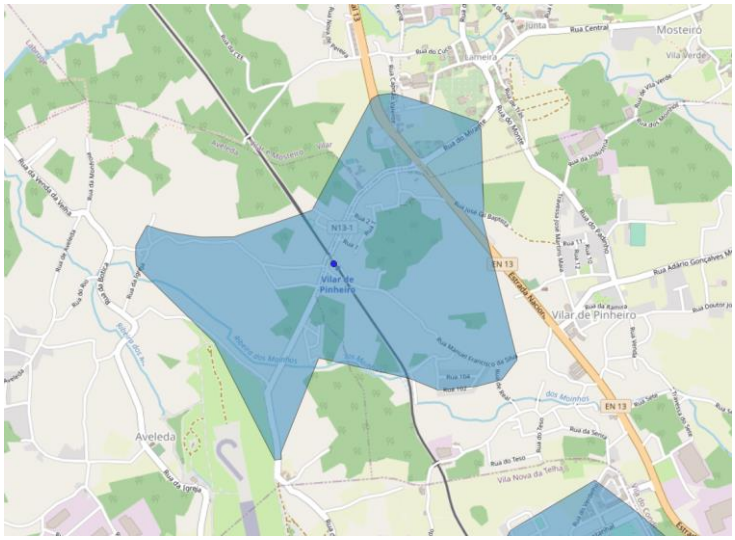


Figure 8 Isochrone from Metro Station in Vila do Conde

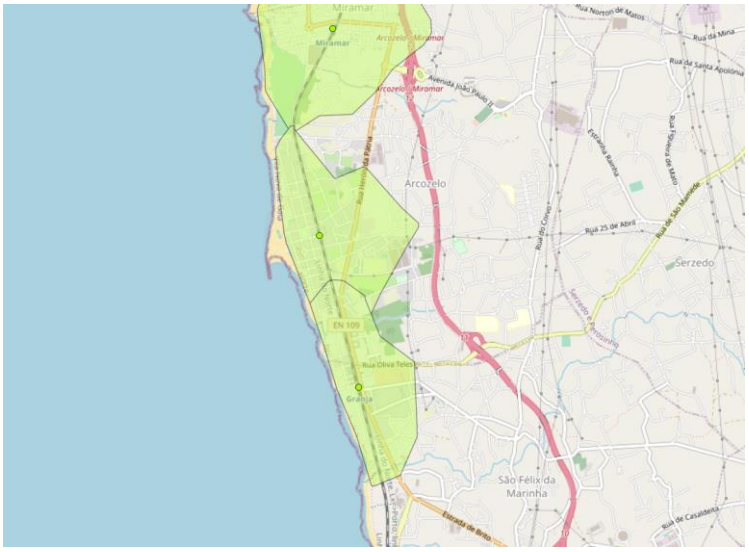


Figure 9 Isochrone from Train Station in Vila Nova de Gaia

The close-up of isochrones show area served along a metro and a train station within a certain travel time. The first image in Vila do Conde council, served area is along main roads and farmlands are not accessible. In the second image, in Vila Nova de Gaia council, the sea is limiting the area comprised by the isochrone. This method presents a considerable advantage than using straight line radiuses (Euclidean distance) in the sense that represents better the distance walked or travelled by an individual within real possibilities considering urban infrastructure.

The limits of each isochrone suggest different boundaries in which individuals who travel over this threshold are socially excluded. The objective will be to achieve accessibility goals to comply within 15-minute accessibility of stations. Accessibility will be sufficient when people are within 15-minutes of at least one public transit station. If distance is too big that this cannot be complied, we will need, as seen later, to administrate vehicles to cover underserved areas and promote accessibility to disadvantaged social groups.

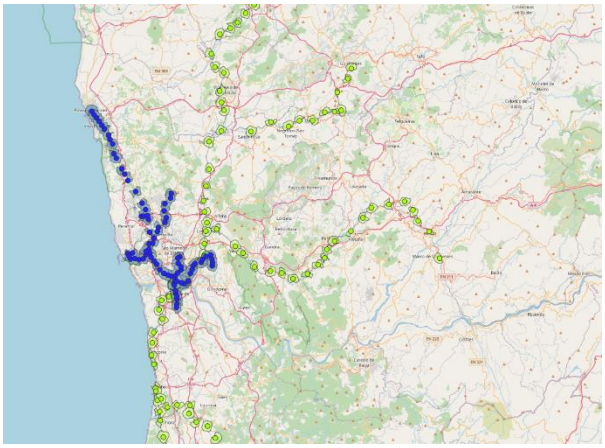


Figure 10 1000m isodistance

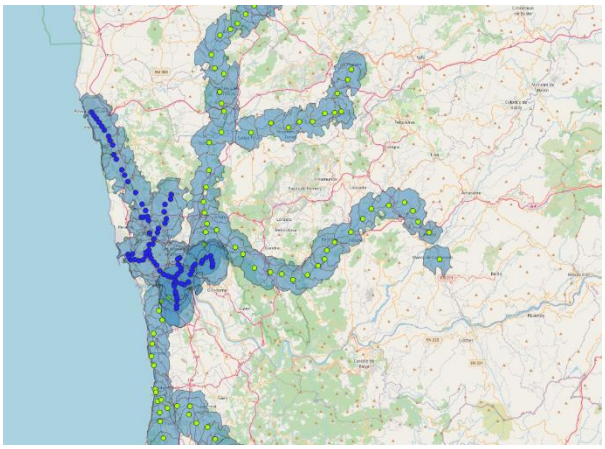


Figure 11 3000m isodistance

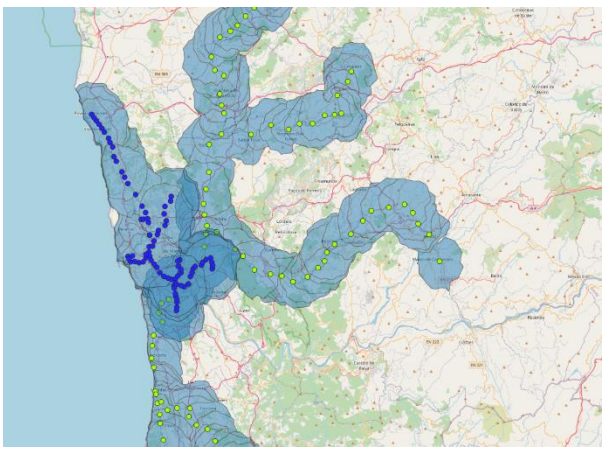


Figure 12 5000m isodistance

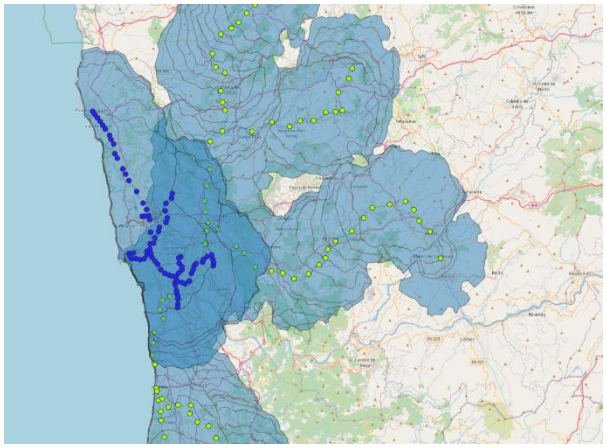


Figure 13 10000m isodistance

The physical intersection of these isochrones with the demographic information obtained from INE for each subsection will determine how many people are served by each station within a 15-minute travel time.

Geographic inequality will be analysed at a civil parish level, but information will be gathered at the smallest level of granularity which are the subsections within them. Therefore, population with accessibility to a station will be considered if the isochrone is touching the subsection in which they live. This means that population reached will be slightly higher than the one really served by the isochrone, but it is an acceptable consideration given that subsections are the smallest cell of information available for demographic information and usually have a surface area covered by only 1 to 5-minute walking distance.

Accessibility is now calculated, for each civil parish as:

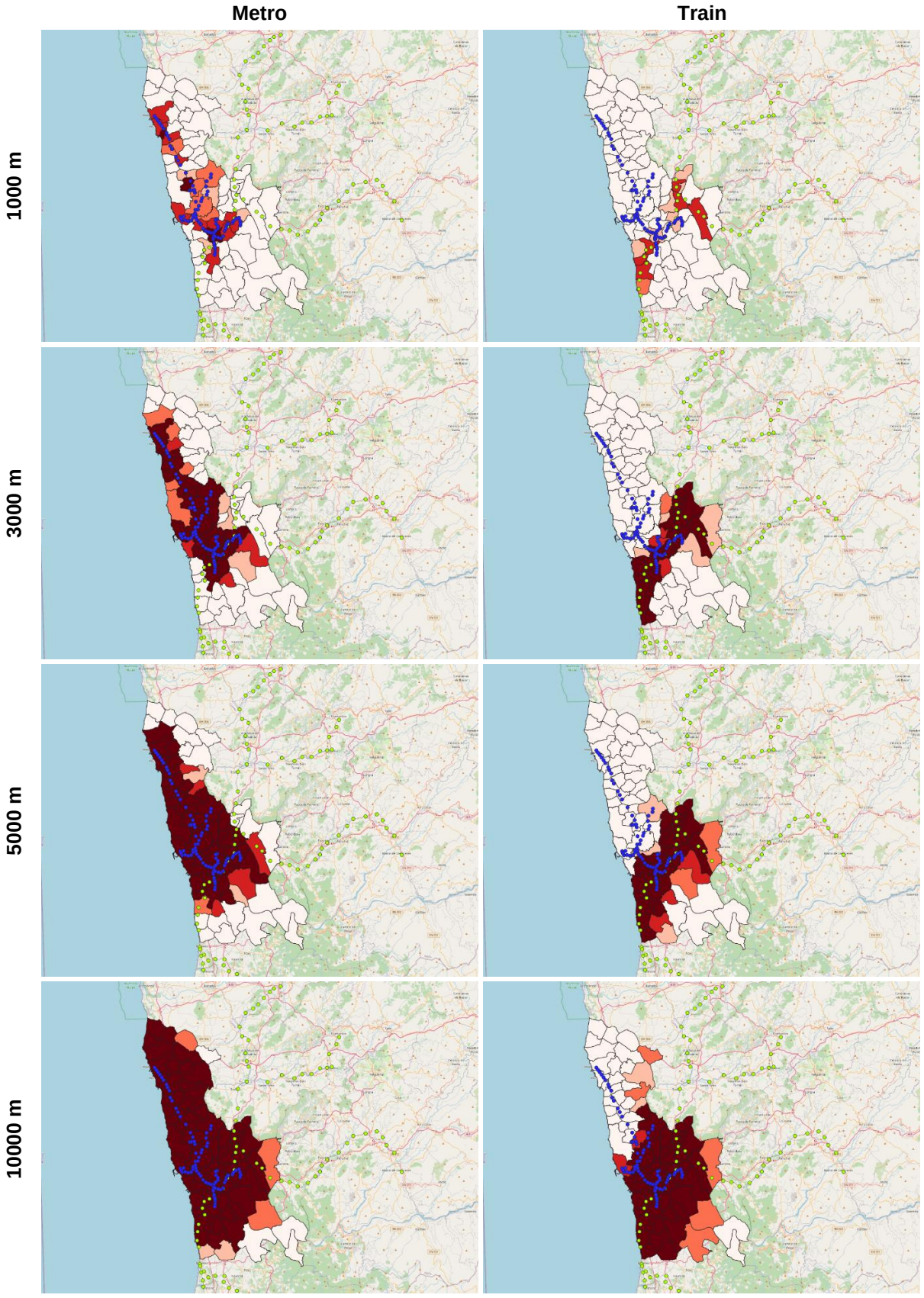
$$Accessibility_{k,j} = \frac{\sum_i^n X_i}{\sum_i^n Y_i}$$

Where,

- k = civil parish
- j = isochrone (1000m, 3000m, 5000m or 10000m)
- i = subsection
- n = number of subsections within civil parish k
- X = population reached by isochrone from station
- Y = total population of the subsection

Example of accessibility levels for train and metro stations, for each isodistance is shown below, with colour coding displaying the percentage of population with accessibility in that civil parish.

Table 3 Percentage of Population with 15-minute access to Public Transit Stations in each Civil Parish



Symbol	Values	Legend
☑	0.00 - 10.00	0 - 10
☑	10.00 - 20.00	10 - 20
☑	20.00 - 30.00	20 - 30
☑	30.00 - 40.00	30 - 40
☑	40.00 - 50.00	40 - 50
☑	50.00 - 60.00	50 - 60
☑	60.00 - 70.00	60 - 70
☑	70.00 - 80.00	70 - 80
☑	80.00 - 90.00	80 - 90
☑	90.00 - 100.00	90 - 100

Figure 14 Levels of Accessibility

Naturally, larger isochrones will cover more surface and therefore serve a greater number of people, showing higher accessibility levels. When comparing each mode of transport, we can observe that metro provides higher levels of accessibility. This can be given because of the number of stations, their distribution, or the density of population living around them.

Figure 15 Accessibility and Distance to Station

Observe that the curve increases steeply and later flattens, meaning that it becomes less effective in terms of providing more accessibility when greater distances are used. This can be given because area covered is overlapped and no new areas are covered, but rather serving repeatedly the same population.

5.2.1 Geographic Inequality Results

Analysing each civil parish, we can map the Lorenz curve and Gini coefficient for each accessibility level, given the 4 set of isochrones studied. The Gini coefficient is a metric that captures the extent to

which the situation in the given area distances from the perfect equality situation, so will help us describe the geographical inequality between people living in each civil parish.

Similar to the way income inequality is often captured, we compute Lorenz curves and Gini coefficients to represent how equally accessibility is distributed for each urban area in our sample. In this case, instead of using the total income distribution available to the accumulated population, we consider the total destinations accessible, or public transport stations. Thus, accumulated income will become accumulated accessibility.[18]

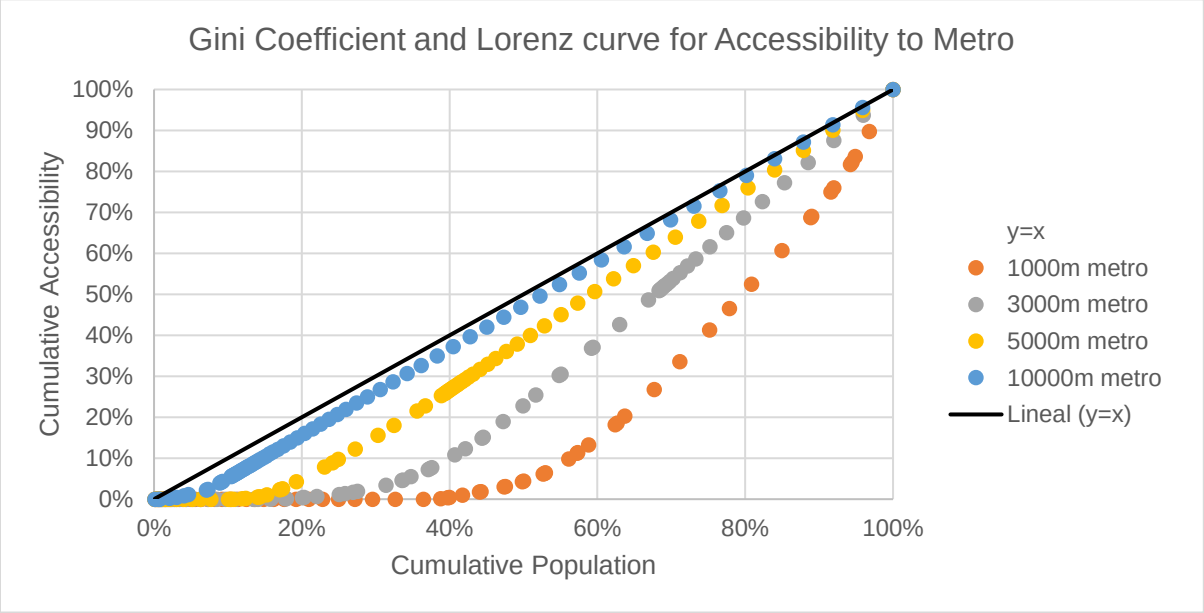


Figure 16 Gini Coefficient and Lorenz curve for Accessibility to Metro

In the graph, each point is a civil parish and represents the cumulative population for each accessibility level. For example, it is read in the following way "40% of the total population live in a civil parish in which 10% or less have access to a metro station within 3000m".

In contrast to wealth or income, which can be quantitatively accumulated, accessibility in this case is measured as a percentage so it cannot be added. However, this approach allows to have a clear comparative scenario of inequality within civil parishes for each isochrone.

[18] Avner and Lall, 2016.

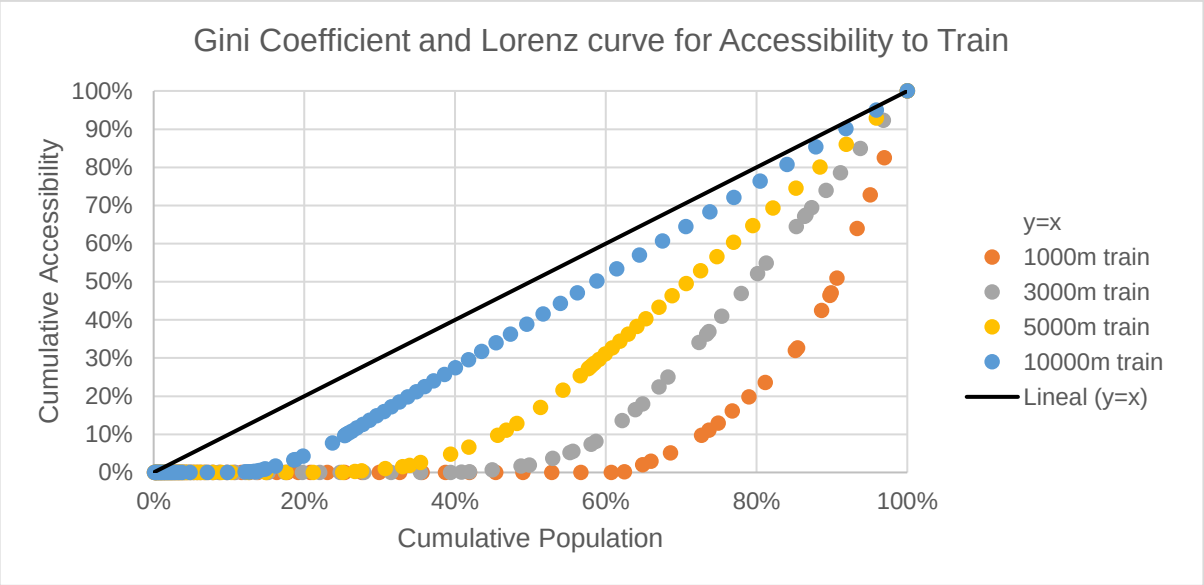


Figure 17 Gini Coefficient and Lorenz curve for Accessibility to Train

Train accessibility is also measured with 4 isochrones, but in this case, we observe greater inequality. This is given because the train network is not as extensive as the metro networks. There are only 2 lines in the region studied and there are much more metro stations spread across the city, meaning greater special coverage. Therefore, we observe a very large population with 0% accessibility to train mode. Even when considering the largest isochrone of 10000m, 15% of population will still be excluded, no matter what.

Table 4 Gini Coefficient for Metro and Train

Gini Coefficients	1000m	3000m	5000m	10000m
Train	0.73	0.54	0.38	0.14
Metro	0.53	0.31	0.15	0.03

The Gini coefficients show inequality in the region, as some people have accessibility and some do not. This is accentuated for the case of the train in comparison to metro, and it diminishes using larger radiuses, which present a possible solution.

5.2.2 Gender Inequality

Another way of examining degrees of inequality within the population studied is by analysing differences in accessibility between men and women. When looking at the demographic information available, males and females might be unevenly distributed and some could have better access to public transport stations. The following graph displays the difference in accessibility levels for gender inequality. The colour coding shows the percentual difference in accessibility of women in comparison to men. Red colour means that women have better accessibility than men, and green means the opposite.

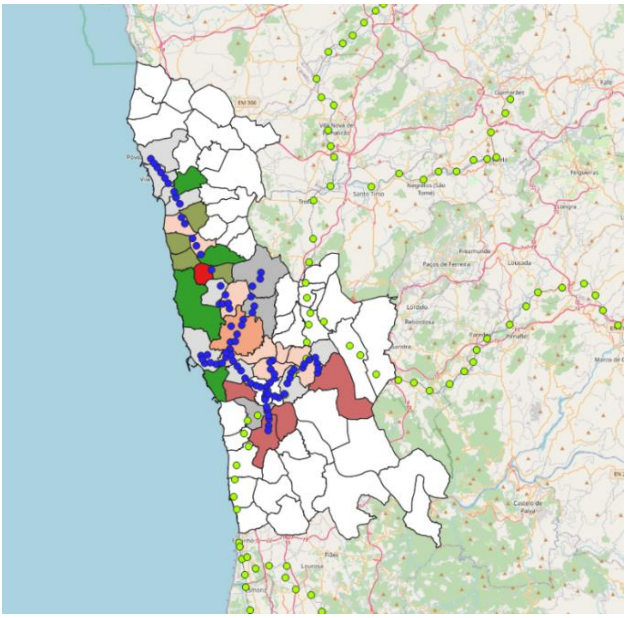


Figure 18 Gender Difference in Accessibility to Metro

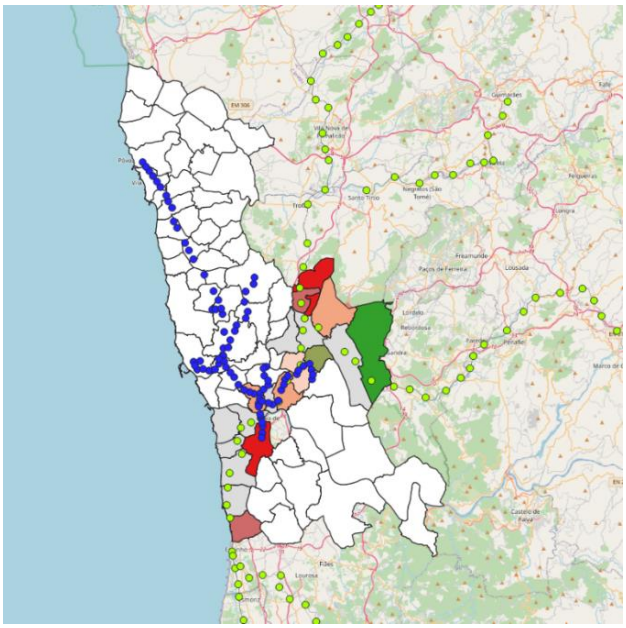


Figure 19 Gender Difference in Accessibility to Train

Symbol	Values	Legend
☑	-40.98690 - -6.00000	-40.987 - -6
☑	-6.00000 - -4.00000	-6 - -4
☑	-4.00000 - -2.00000	-4 - -2
☑	-2.00000 - -0.00001	-2 - 0
☑	-0.00001 - 0.00001	0 - 0
☑	0.00001 - 2.00000	0 - 2
☑	2.00000 - 4.00000	2 - 4
☑	4.00000 - 6.00000	4 - 6
☑	6.00000 - 11.25288	6 - 11.253

Figure 20 Levels of Accessibility for Gender Inequality

Evidence suggests that there is not significant inequality in accessibility between men and women. When looking at metro accessibility, there will be some Southern areas in which women have better accessibility but the opposite will be given in the Northern sectors. Train accessibility leads to a similar conclusion in which some central areas show better accessibility for males but others show better accessibility for women.

Overall, gender inequality is contained within a ±5% which is accepted as an aleatory distribution. Overall results are that women have a 3.9% access more to metro than men and 1.6% more to train. There does not seem to be exclusion or advantages to either males or females in providing access to public transport, so we conclude there is no significant gender inequality in the case studied.

5.2.3 Age Inequality

The results of measuring inequality while separating in four different age groups are the following:

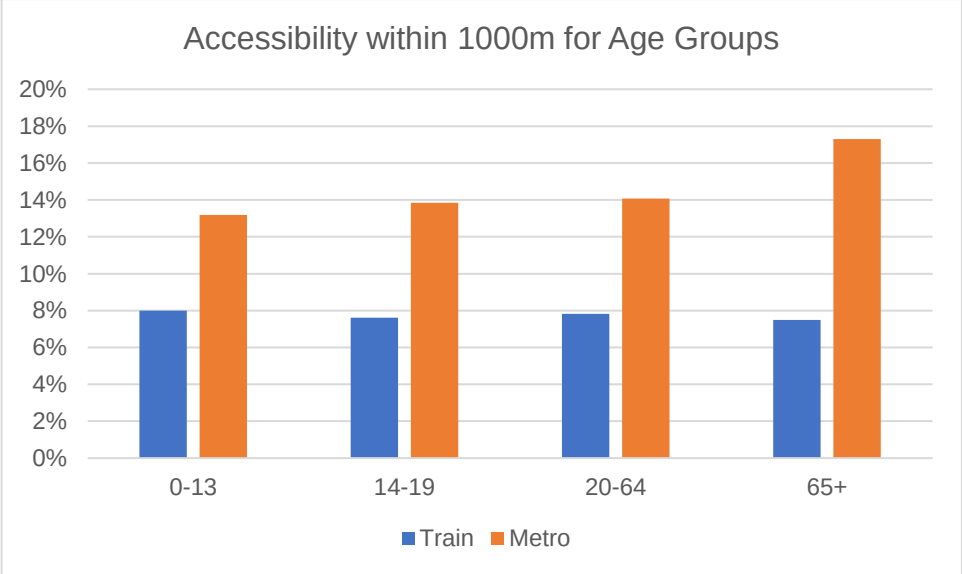


Figure 21 Accessibility for each Age Group

Table 5 Accessibility to Train and Metro for each Age Group

	0-13	14-19	20-64	65+
Train	8%	8%	8%	7%
Metro	13%	14%	14%	17%

As seen previously, values for accessibility levels are higher for metro than for train, overall. However, when measuring differences between groups, there is more equality for train accessibility, given that values roughly change. Metro accessibility is within the 13% to 17% range, showing a greater gap between groups, favouring the elder.

This could be given because group 0-13 can be considered the most car-dependant, given that children need to access activities such as school, leisure, parks and the preferred mode is car, so there is no need of living within access to a public transit station. On the same line, the 65+ group accept shorter walks to public transport stations so they need to live closer. It is most likely that property is more

expensive closer to public transport stations, so elder groups might also be wealthier than the younger groups which would explain the disparity of results.

5.2.4 CONCLUSIONS OF RESULTS

In first place, it is very straight-forward that underserved areas improve their accessibility with larger radiuses of coverage from the metro or train stations. In other words, accessibility improves by considering "accessible" more distant locations. This might seem quite obvious, but it is highlighted to reinforce the concept that accessibility levels are actionable and can be improved.

However, the accessibility curve flattens as the graphic shows, reaching a limit. Larger isochrones will serve a larger area but in a more inefficient way, as they tend to overlap and provide accessibility to the same group of people. Certain areas tend to reach a limit in which an isochrone provides full accessibility to the civil parish and larger isochrones will only overlap with other already served areas. At the same time, cost increases for larger isochrones, meaning that reaching 100% will require larger efforts and further policies will be needed tackle this issue.

When focusing on inequality between areas, Central Porto is better supplied with both train and metro stations as it concentrates large extensions of the network. This proves existing geographical inequality between civil parishes. However, Gini indicator is closer to 0 (more equal) when larger isochrones are used. It not only provides better accessibility levels overall, but also less difference between groups, meaning that inequality is tackled through vertical equity principles, serving the most in need.

There is no considerable gender inequality, between males and females as they have usually equal accessibility. However, there is a tendency for elder people to be better served by public transport stations.

When considering the mode type, metro better serves civil parishes, has higher levels of accessibility and less geographical inequality than train, as it has lower Gini coefficients. So, train is less accessible, not because it is more expensive, as traditionally thought, but because it is less reachable to people and have stronger presence in certain areas. The most equitable situation would be given by using isochrones that serve 10000m from metro stations, having a Gini coefficient of 0,03. However, as explained, this can be unnecessarily costly and we need to focus on which areas are the most in need.

Finally, results are inevitably dependent on the location of the stations and how the network is built and distributed. Within the periphery of the city, stations are further away so they will need larger isochrones while in urban areas there is a denser concentration of stations of both metro and train, so the need for accessibility is lower.

In other words, first-mile and last-mile solutions will not solve the public transport network problems entirely. There is a limit (not only cost effective, but also practical) to which this solution can be implemented.

5.3 DIMINISHING INEQUALITY IN ACCESSIBILITY TO TRANSPORT NETWORK

To improve the described situation in the Great Porto metropolitan area, we need to have higher accessibility values for the disfavoured groups. This will primarily decrease inequality levels and therefore have lower Gini coefficient values.

Vertical equity policies need to be strategically aimed at groups in need and cannot be generalized. In this case, we are trying to solve geographical inequality and therefore we will focus on civil parishes with lower accessibility levels, which are usually further away from Porto County (the centre of the metropolitan area). Remembering the objective set:

All civil parishes should have 100% of their population with at least 15-minute accessibility to a public transport station.

We therefore need to think of solutions to achieve this accessibility goal. It is important to stress that accessibility is given through a time threshold, not distance. Then we can think of different transport modes that cover larger distances in 15-minutes for having different travelling speed. These vehicles will be our first-mile and last-mile solutions to improve equity and their characteristics are described below.

5.3.1 MICRO-MOBILITY

Micro-mobility is a new kind of travel mode that it is open to multiple criteria in its definition, as every specialist has its own vision and criteria for including vehicles. It is commonly accepted to characterize small vehicles (maximum weigh can vary from 35kg up to 100kg) and for single passengers. Their speed is rarely above 25 km/h and they are usually used for doing short-distance trips of up to 30 minutes. They can be individually owned (private) or shared, installed by shared mobility operators. Examples of micro-mobility vehicles are human or electrically powered bikes, mopeds, scooters, hoverboards and skateboards, among others. The fact of being small vehicles, electric and of shared use makes them green and sustainable in a way and less harmful for traffic and congestion in comparison to cars.

There is a growing consensus that micromobility can be an important piece in the jigsaw of the network of public and semi-public transport, improving connectivity to rail stations. There is currently a grey zone in legislation in which any operator can build their mobility service and deploy their fleet in a couple of weeks. The truth is, that micro-mobility provides with a wide flexibility of usage and can be suitable for riding in different surfaces and environments. Small electric vehicles are an inexpensive and practical transportation that if effectively accommodated could be used for first-mile and last-mile trips to complement public transport.

5.3.2 FIRST-MILE AND LAST-MILE

The ‘first and last-mile’ is a term that describes the beginning and end of an individual’s public transport journey. Given that the bus stop or station is rarely the destination we are interested in reaching, an additional trip is included from the transit stop to our end point. This is commonly referred to as last-mile trip, being first-mile the trip from our origin to the transit stop. In most cases, first-mile and last-mile trips are done walking, and if the public transport network is well designed, it should only be a short-distance walk.

Whilst often short in distance, the first and last legs of public transport-based journeys are often the most challenging when we realise that most cities are built for vehicles, not people. Essentially, the first and last-mile problem is that public transport doesn’t take us exactly where we want to go and walking isn’t always the most convenient option. At the same time, first and last-mile trips are disproportionately highly valued by commuters relative to the rest of their journey. This is, penalized more when choosing a travelling mode, for creating high disutility.

Figure 22 First and Last Mile trips

In order to solve the dysconnectivity between the transit network and people's origin and destinations, cities are increasingly turning to micro-mobility services to complement public transportation. Micro-mobility solutions for first and last-mile trips offer a high level of freedom and movement. By providing a reliable, safe, and faster service to travel, public transport can be complemented and travelling times diminished, or more opportunities become accessible. At the same time, reducing the friction of the first and last-mile makes public transport more attractive and better positioned to compete with unsustainable travel modes like the private car.

Many different vehicles address different mobility issues, but the principal challenge that cities face is that there often isn't a one-size-fits-all solution for every travel situation. While the inconvenient part between leaving origin and arriving at your destination is improved, and at the same time population served by transit stops increased, there needs to be a special attention in the type of vehicles implemented and the specific user at which they are aimed at.

5.3.3 VEHICLES

To increase public transport spatial coverage and provide better accessibility, micro-mobility vehicles are used to solve first and last-mile trips. The type of vehicles chosen will define the effectiveness of our policies, primarily based on the following characteristics:

- **Speed**, as it will define the distance covered by an isochrone and therefore serve more or less population.
- **Target audience** and usability, as not every vehicle is intended for the same type of person. The main focus of this will be age groups.

Following the 15-minute accessibility concept, we will suggest vehicles that are able to cover area in this amount of time and provide accessibility to the civil parishes in need to reduce geographic inequality. The type of travel modes can be within a wide range, but the ones being considered in this scenario are characterized in the following way:

- **Walking**: Universal mode of transport, ubiquitous, and equitable. For everyone, with the exception of people with physical disabilities or motor impairments. Needs relatively low infrastructure costs.

- **E-Scooter:** Needs bike-lanes to circulate or can use roads, with some risk of danger. Require no effort as it is electric but not suitable for elder because requires strong standing position and maintaining balance, as well as driving abilities[19]. Only available for +13 age groups.
- **E-Bike:** Needs cycling infrastructure, or can use the roads with some risk of danger. Requires physical effort, which can be diminished if vehicle is electric but are not recommended for elder people. Cannot take passengers, only available for +13. Occupy slightly more space than e-scooters when parked.
- **Golf Cart:** Size of a small car, requires parking space and can be used on roads. Requires very little physical input, only driving skills. Can take passengers.
- **Electric Car:** Requires parking space, a driving licence, a contract agreement and insurance with the operator, not allowed for U18. Creates congestions and can be driven at higher speeds, with risk of accidents.

Table 6 Vehicle Characteristics and Usability

Mobility Mode	Speed (km/h)	Distance covered in 15 minutes (m)	Usability (age groups)			
			0-13	14-19	20-64	65+
Walking	4	1000	Yes	Yes	Yes	Yes
E-Scooter	12	3000	No	Yes	Yes	No
E-Bike	20	5000	No	Yes	Yes	No
Golf Cart	20	5000	Partially	Partially	Yes	Yes
Electric Car	40	10000	Partially	Partially	Yes	Yes

When looking at usability, age groups are divided in this way for the following reasons:

- **0-13 years old:** need parent supervision and are usually dependant on ridership.
- **14-19 years old:** can usually ride bicycles and scooters, but are not old enough to drive motorized vehicles as they cannot have a driving licence.
- **20-64 years old**: usually no mobility restrictions, independent and able to drive practically any vehicle.
- **65+ years old**: although still independent, might start becoming more dependent and develop mobility restrictions as age increases.

When vehicles are assigned to each civil parish, benefits of these vehicles will be allocated towards this area only, considering the type of users that can take advantage from them. If the usability is partial, it will be considered as 50% of that age group. We will also take into account that areas between civil parishes where vehicles are deployed and the transit station considered do not increase their accessibility levels, even though vehicles travel through them. This is, if they have a 15-minute accessibility for their population, their accessibility will not increase even further as distribution policies will be put in place to take vehicles back to locations in need, in case users finish their trips in better served areas.

[19] United Nations, 2019

5.4 NEW GEOGRAPHICAL INEQUALITY SCENARIO

Remembering our goal, in which we aim to guarantee every civil parish (egalitarianism) to have accessibility of at least 15 minutes (sufficientarianism) to metro or train stations, we analyse the achieved scenario. By allocating vehicles to underserved areas, new accessibility levels would be the following:

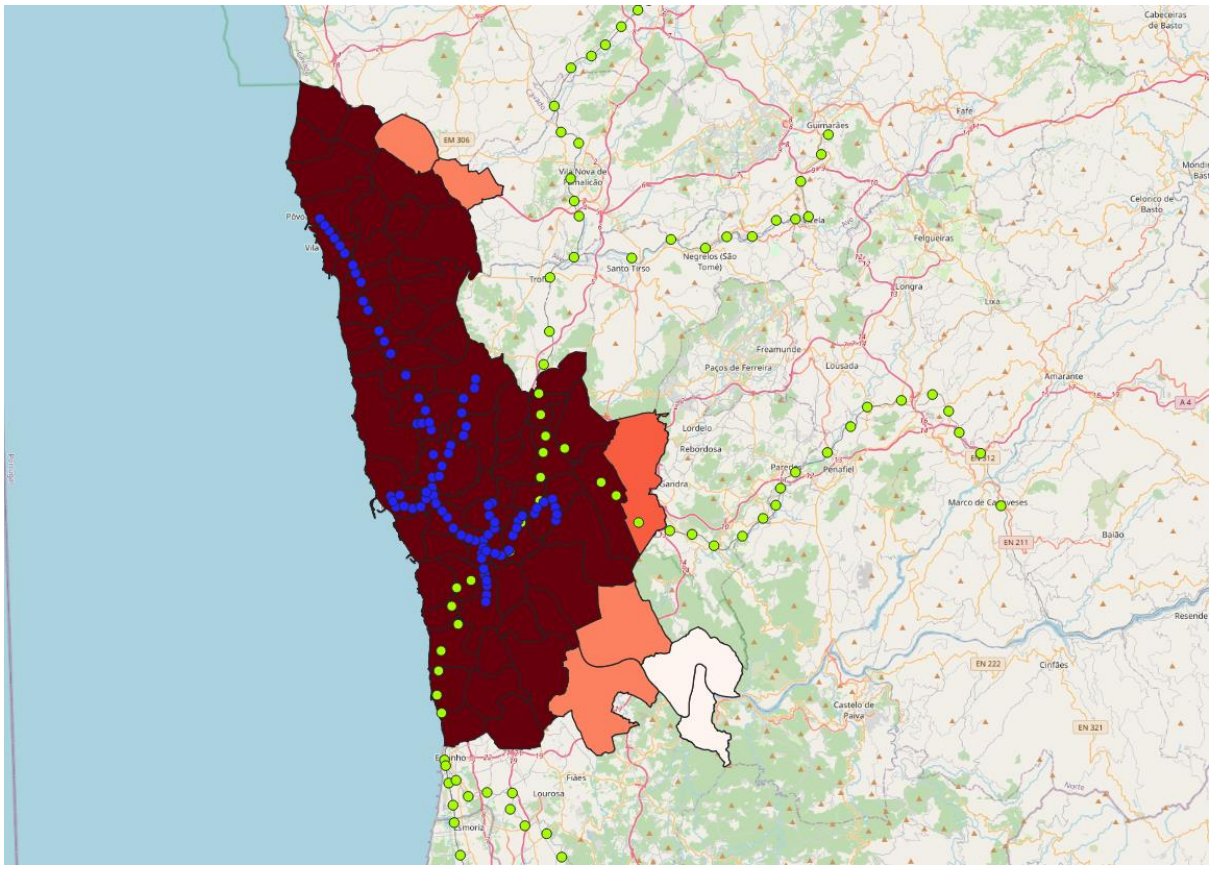


Figure 23 New Accessibility Levels after Implementation of Vehicles

Symbol	Values	Legend
☑	0.00 - 10.00	0 - 10
☑	10.00 - 20.00	10 - 20
☑	20.00 - 30.00	20 - 30
☑	30.00 - 40.00	30 - 40
☑	40.00 - 50.00	40 - 50
☑	50.00 - 60.00	50 - 60
☑	60.00 - 70.00	60 - 70
☑	70.00 - 80.00	70 - 80
☑	80.00 - 90.00	80 - 90
☑	90.00 - 100.00	90 - 100

Figure 24 Levels of Accessibility

Colour-coding shows a percentage scale of accessibility given the micro-mobility solutions applied to reach public transport stations. Note that 69 out of the 76 civil parishes studied have an accessibility level of 90-100%. This means, vehicles allocated serve all of the residents by covering completely the area of the civil parish within a 15-minute isochrone. However, there are 7 civil parishes that do not reach the 90-100% level, even when using the largest isochrone available, equivalent to a 15-minute

car travel. These cases show that first-mile and last-mile solutions in spite of being efficient for many cases, cannot be entirely dependent to complement public transport and structural improvements to the transit network are as well necessary.

The isodistances needed to achieve our goal of at least 15-minute accessibility for every civil parish as shown previously, would be the following:

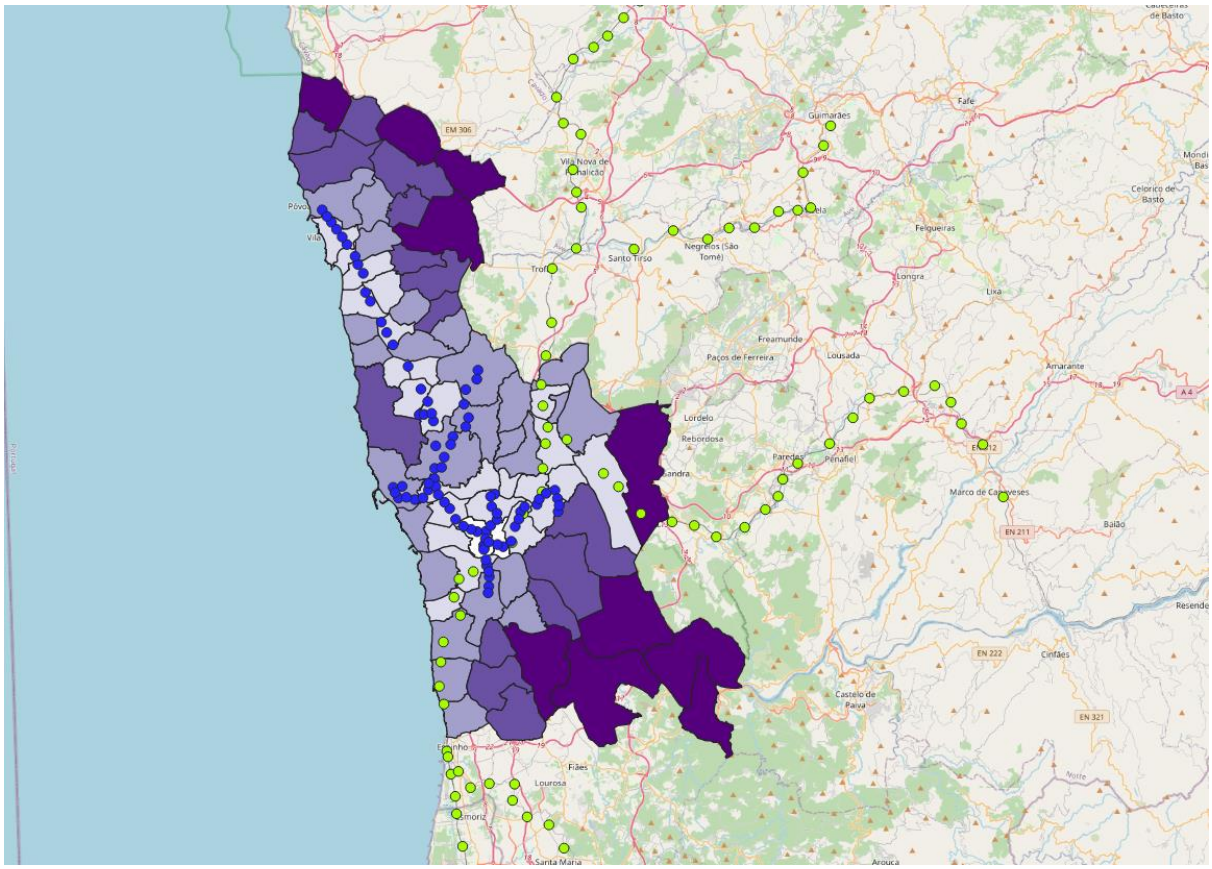


Figure 25 Isodistances in each Civil Parish to provide total Accessibility

Symbol	Value	Legend
☑	1000m	1000m
☑	3000m	3000m
☑	5000m	5000m
☑	10000m	10000m
☑	Not Accessible	Not Accessible

Figure 26 Isodistance Levels

Not accessible means that it does not achieve fully our objective of having 100% of the population covered by a metro or train station with the maximum isochrone available. These cases fail to meet our goal, as they do not meet the sufficientarianism and social inclusion goals.

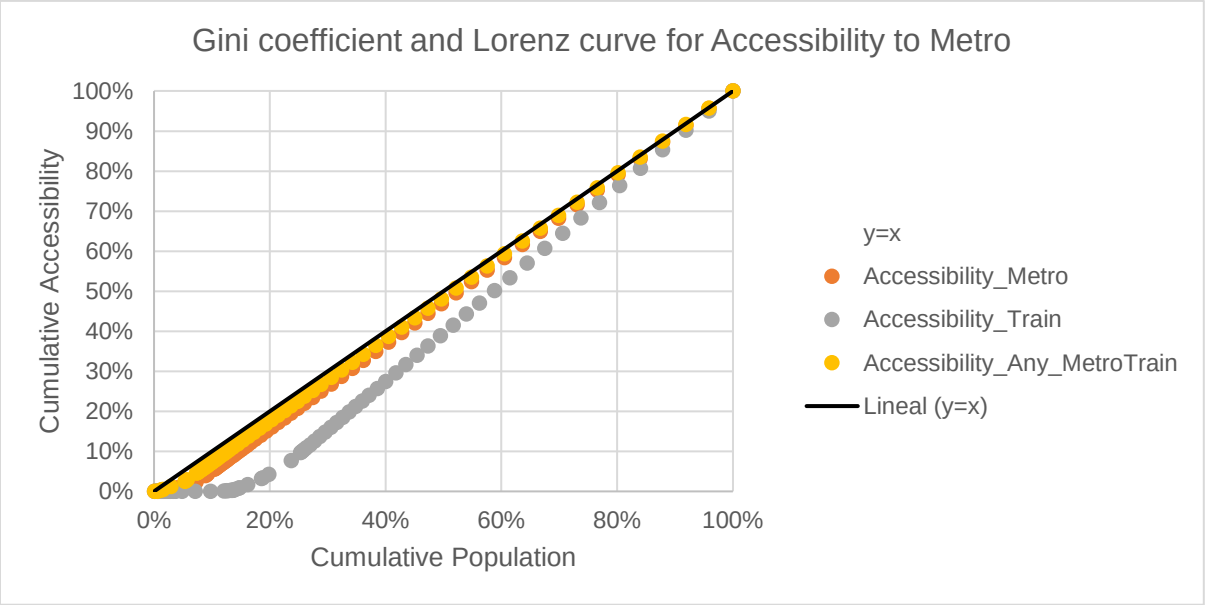


Figure 27 New Gini coefficient and Lorenz curve for Accessibility to Metro

Table 7 New Gini Coefficients for Train and Metro

Gini Coefficients	1000m
Train	0.14
Metro	0.03
Train or Metro	0.00

The Lorenz curve is, in comparison to previous scenario, much closer to the perfect equality distribution. This implies that everyone has equal access to the public transport network, as seen in the previous map. Gini coefficient for train is 0.14 and for metro 0.03, which shows a more equitable scenario for metro. If considering any of them, the Gini value is 0.004 which pictures an almost perfectly equal scenario.

The vehicle distribution policy is an example of vertical equity. Zones needing special treatment to accessing to public transportation network are given the resources needed. By having disproportionate benefits from public resources, an equitable situation in which all areas have equal access to opportunities is achieved. However, we need to evaluate the utilization of this vehicles and if they serve adequately the residents of these civil parishes.

5. 5 New Demographic Inequality Scenario

The transport mode or vehicles used to cover the distance showed by the 15-minute isochrones are the following:

Table 8 Civil Parishes Served by each Vehicle

Mobility Mode	Civil Parishes Served	Population Reached
Walking	2	64705
E-Scooter	23	445661
E-bike / Golf Cart	25	463907
Electric Car	15	202470

This information provides a magnitude of the resources needed to invest but is incomplete in terms of equity analysis. As described by the characteristics of vehicles, each one is aimed at a specific target, or in other words, has limitations to who can used it and who cannot. Therefore, it would be incorrect to consider everyone in the civil parish to have accessibility, just because there is a vehicle serving that area. This is a common misconception and can happen if planning does not consider people's needs. While intending to solve geographic inequality by having a larger spatial coverage, there might be another type of inequality that is increasing if people's needs, abilities and characteristics are not taken into account.

What we need to do is to calculate demographic inequality in the new scenario and compare it to the initial scenario. As there are no vehicles aimed at male or females, this type of inequality will not be considered and will be considered as equal in both scenarios. However, when comparing between age groups we observe the following:

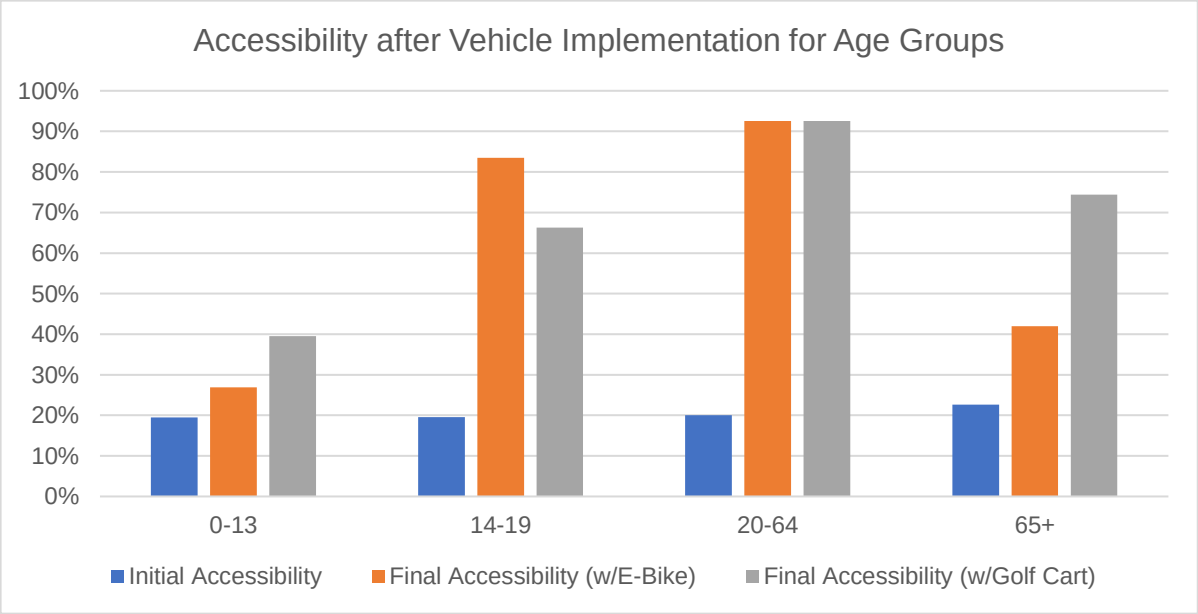


Figure 28 Accessibility after Vehicle Implementation for Age Groups

The analysis done compares the initial accessibility levels for each age group with two alternative scenarios, in which E-Bikes or Golf carts are used. As mentioned before, these vehicles are equivalent in speed so they cover the same distance in the same time, but their characteristics include or exclude some age groups.

What we can observe is that overall accessibility is increased with the introduction of vehicles, which is a conclusion we are reaffirming. The most favoured sector is the 20-64 age group, given that every vehicle suits them well. The 0-13 group depends on someone else driving for them, so the golf cart is slightly more effective than the e-bike. The 14-19 is in a similar situation relating dependency, but at this age they can ride bicycles on their own, providing them more accessibility. Finally, the 65+ age group is better favoured with the golf cart, which does not have such physical demand as an e-bike.

When looking at inequality, the most equitable vehicle between these two is the Golf Cart. This is because even though both solutions increase overall accessibility, the Golf Cart increases more for the most disadvantaged groups, which are 0-13 and 65+, in relation to e-Bike. These two groups have the shortest bars, and even though E-Bike solutions are effective in increasing accessibility, Golf Cart are not only effective but also reduce inequality. Even though it is more expensive and space demanding, golf carts provide a better solution for inequality in the case studied.

The objective of the comparison is not to select a winner. All vehicles have advantages and disadvantages in terms of cost, space demanded, target audience, energy consumption, intermodality possibilities and so on. Each vehicle can be used in different cities and different contexts depending on demographics (i.e., a student city having more scooters to travel within campus) and distances needed to cover (i.e., e-bicycles being more suitable for rural areas than scooters). The comparison is used to determine which vehicle is better suited for the context analysed and the users intended.

A solution should be evaluated on the usability of it. If people cannot use the vehicles provided, then they will be ineffective. This is common in transport planning and should be evaluated through equity policies. In the following chapter we will analyse additional ways in which policies should be inclusive.

6

GUIDELINES FOR IMPLEMENTATION OF SHARED MOBILITY POLICIES

6.1 GOVERNMENT ROLE

As we are discussing a social issue, government's participation will be essential to tackle problems that free-market leaves unattended. It is government's duty and responsibility to consider equity goals and solve injustice created by inequality in transport.

This can be achieved by allocating resources to those in need, by directing public investment and subsidies to disadvantaged groups. The case studied in Porto is an example of this, in which vehicles were supplied by public authorities. Some transport policies directly aim to reduce transport-related social exclusion through the introduction of new transport services and a variety of supporting measures. People experiencing social exclusion are rarely willing (or able) to pay the full cost of these new services and so they must be subsidised through the public purse.

But intervention in private activity can also be a form of effective policies. Equity goals can be achieved by regulating and enforcing private mobility operators, such as for example, determining operating hours and fleet distribution.

First-mile and last-mile solutions explained previously are sustained through a 4-legged strategy:

1. Fleet availability
2. Payments, technology and information
3. Price
4. Universal Design

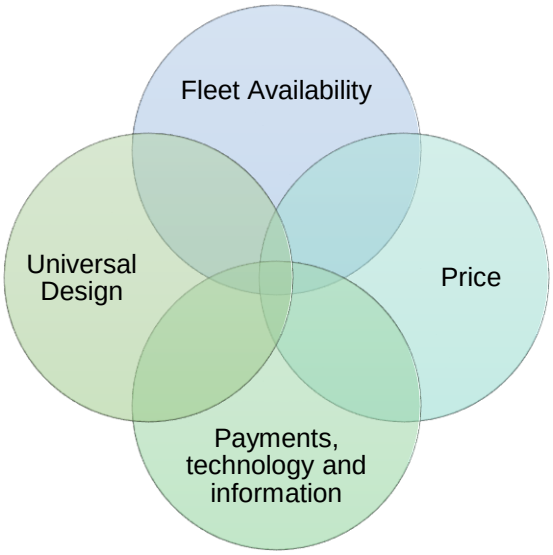


Figure 29 Strategy for implementing First and Last-mile Solutions

6.1.1 Fleet Availability and Distribution

Reality is that many cities have disadvantaged populations located throughout their city boundaries. Many cities are developing policies that require or incentivize companies to place a certain number or percentage of vehicles in specific geographic areas to meet equity or broader transportation planning objectives. Without this incentive, there is no reason to locate vehicles in less profitable areas following strictly market-driven conditions. Government intervention, control and subsidies are crucial to make this situation turn from revenue-oriented to equity-oriented.

Cities are encouraged to explore incentives over strict vehicle minimums which may be difficult for mobility operators to meet, particularly if new mobility solutions are welcome in the community. Policies with strict minimums on the placement of vehicles can sometimes make it impossible for a private mobility company to sustain operations in a city, potentially resulting in their departure.

Incentives from public authorities to private operators can come in the following ways:

- Through determining operating hours, to guarantee availability of rides such as commuting for specific social groups.
- Through minimum number of vehicles in districts or neighbourhoods. This can be measured as in residents per vehicle (per capita) or vehicle density (per square kilometre) goal, depending what kind of objective the city has in mind.
- Through extra vehicles licensed if deployed in underserved areas. For example, additional 500 vehicles can be permitted to the operator that maintains 2/3 of vehicles operating outside the city centre.
- Similarly, the fee for the licence of vehicles in underserved areas could be lower, or even subsidized.

Measuring the availability of vehicles is relatively simple and can be done through GPS- or location-based data of vehicle locations. However, measure equitable utilization of vehicles is more challenging. Shared mobility operators could potentially distribute vehicles equitably across the city, but they cannot guarantee that people of all income levels, ages, and backgrounds will use them.

Therefore, it is necessary for the public authorities to monitor and cross information with demographic data of adopters and non-adopters of mobility services to measure equitable access.

6.1.2 Pricing

The main principle behind pricing is that people need to be able to afford transport, especially economically disadvantaged people.

Public transport will not have strong revenue orientation, as compared to private companies. But in both cases, there can and must be a subsidy allocated in an efficient way to guarantee equity.

- Discounts on memberships or subscriptions for low-income individuals will improve access to micromobility, such as the implemented cases of operators Lime and Spin. Nice Ride in Minneapolis has an equity subscription plan of $5/year instead of $75, including 60 minutes riding time per day.
- Subsidizing per ride, as in the case of the city of Los Angeles, where an effective strategy is to subsidize rides in economically challenged neighbourhoods. Depending on the city's shared mobility scenario, it can also work as imposing a fee to better served areas. These policies can work individually or combined.
- Eliminating the base fee for anyone who is enrolled or eligible for a state or federal assistance program.
- Implementing discounts for rides to specific areas, considered "equity zones", to transfer this benefit to their residents. This can be determined through the rider's zip code address.

6.1.3 Payments, Technology and Information

The concept of accessibility describes the easiness of accessing opportunities, activities or destinations. This, as studied in this work, can be related to the availability of public transportation. But it has other complementary topics that are important to include in the analysis when thinking about equity and equal opportunities.

Regarding payment type, technology options and availability of information, policies should be executed guaranteeing accessibility to everyone through different choices.

- Many private operators require bank accounts and/or credit cards, which are not as frequent in less-favoured economical groups. Payment options for shared mobility and private operators should be integrated with the normal public transport card.
- Cards should be able to be bought in kiosks and normal convenience stores with the possibility of being prepaid, not only linked to a credit card.
- Technology is usually accepted by the younger and wealthier groups at the beginning. When it becomes more widespread and popular, prices tend to decrease as competitors join the game. This applies to shared mobility operators, MaaS software and other technological improvements to transport. It is important that there is a conscious approach to technological incursion for it to be inclusive.
- While smartphones provide a great advantage, their access is also limited. There should be an offline payment and information alternative. This applies also to data plans, and free wi-fi should be provided when available.

- Information of public transport schedules, fares, routes, should be displayed in printed format on stops for people without smartphones or internet to be able to access to information.
- For contactless payments, not only NFC technology through smartphone should be enabled but also contactless payments through cards. As mentioned before, this should also be enabled through the local transport smartcard.
- Privacy agreements should benefit the user and there should not be unnecessary data required, especially regarding personal information when register and logging in.
- Software and customer service should be multilingual, to serve immigrants, tourists and people who do not speak local language.

Through these practices, a higher level of engagements with minorities can be achieved and a more equitable scenario within transportation where more people have easiness to pay and understand information.

6.1.4 Universal Design

Universal Design is the design and composition of an environment so that it can be accessed, understood and used to the greatest extent possible by all people regardless of their age, size, ability or disability.[20]

It is necessary to have a direct community engagement during the design phase to understand problematics and challenges. Vehicles should contemplate the user at which is aimed at, and allow for different routes and purposes.

[Image: courtesy Teague]

Figure 30 Universal Design Scooter

[20] http://universaldesign.ie/What-is-Universal-Design/

The image is an example of a universal designed e-scooter. Seating allows elder and people with disabilities to use them in a safe way, with lower risk of falling. The stowage option for carrying bags and lower centre of gravity also prevents accidents. Big wheels make the vehicle comfortable and resilient against uneven surfaces and bumps. It is also a more intermodal-friendly vehicle which intends to have fewer problematic interactions with pedestrians. Inclusive vehicles would close the gap between social groups such as elders and young.

Universal design should also apply to infrastructure. Roads need to allow different transport modes and vehicle types. Cycling lanes are recommended for scooters and bicycles, but also road should have flat surface, smooth materials and good maintenance to embrace all kind of vehicles regarding their speed, size and weight.

6.2 Benefits of Shared Micro-mobility

E-scooters, e-bikes, mopeds and other type of vehicles conform the contemporary scenario of shared micromobility. New forms of mobility are usually unequal and exclusive by nature at the beginning, as they are aimed at early adopters, wealthy and techies. This work has focused on the benefits of these forms of vehicles because we believe there is an enormous potential to transform these vehicles into tools for solving equity problems in urban areas. If applied correctly, there are many advantages for shared micro-mobility that have been explained throughout this work which include:

- Flexibility and rapidness to deploy in response to demand.
- Demand can be distributed to unsaturated stations.
- Complements transportation coverage by serving larger areas and reduces transit deserts.
- Cost-efficient solution in comparison to other public transportation projects.
- Can serve as a gateway to public transport modes, attracting new users.
- Micromobility infrastructure is non-expensive, which allows relatively cheap modifications to the existing urban form.
- Clean and sustainable modes from being electric.
- Can help decrease traffic and congestion by replacing car travels.
- More people can use micromobility than just car drivers.
- Restricted speed and weight of vehicles better fit with the human scale of a city.
- Better for pedestrian safety, in comparison to cars.
- Technology leverage and incorporating new tools such as location-based information.
- Possibility of linking demographic information from registrations.
- Provide granular information about common routes, hours of use and hotspots in the city.
- Cities can control pricing, number of vehicles, routes, deployment strategies and availability.
- Flexibility in routes and tailor-made solutions for individuals.

Micromobility can rival the flexibility of the car, but be accessible for more people, while allowing passengers to travel more quickly than walking, and with less effort than cycling. If designed for and planned appropriately, micromobility can provide a highly effective first and last mile transport

option, complementing and expanding the public transport network, as well as potentially facilitating development at increased densities in outer zones from cities.

6.3 PUBLIC POLICY RECOMMENDATIONS

As a final recommendation, 5 key messages are passed to make an effective implementation of mobility solutions. In first place, transport should be acknowledged with its justified importance of being a cross-cutting activity to provide connectivity and contribute to raising human capital. Secondly, the rights of all people should be protected as for them to live in a high-quality local environment. Third, there should be an explicit analysis that demonstrates who are the winners and losers from decisions involving the allocation of public funds. Fourth, inequality should be addressed by giving priority for investment and subsidy to meet the needs of the disadvantaged in an affordable way. Finally, the situation needs to be re-assessed, results measured in different ways to determine the impact of policies, identify new vulnerable sectors and set new goals for reducing inequality.

Our suggestion is that policymakers can use the described ethical perspectives and indicators explained in this work to determine the equity of their policies decisions and to set minimum standards for local transport delivery. This will help them become more confident in the development and adoption of new decision frameworks that promote accessibility over mobility and which also disaggregate the costs and benefits of transport policies over particular areas or for specific under-served population groups.

7
CONCLUSION

Inequality is endemic in transport, as the differences in needs, abilities and characteristics of people result in personal preferences that shape an aggregated travel demand but is formed by unequal components. Whether the degree of inequality is accepted will depend on if these individual preferences correspond to basic human rights that are being unfulfilled. The role of transportation is to provide people access to opportunities so they can engage with activities such as jobs, education and health. Public transportation, specifically, should commit to this mission while being inclusive, affordable and safe. If transport planners fail to achieve this goal, increasing inequality can further aggravate a social justice issue.

While inequality can be shaped in different ways, in this work we focused primarily on geographic inequality and then how this impacted demographically in social groups. Modern urban problematics such as gentrification and segregation are examples of geographical inequality and result in social exclusion which needs to be undertaken in transport planning.

We've seen that public policy-making needs to be concerned in addressing inequality, not only for ethical reasons but also because equitable societies promote well-being, social cohesion, trust, safety and ultimately economic growth. There are strong philosophical theories that support planning for equity and challenge traditional transport planning based on utilitarianism. Addressing inequality creates long-term benefits, but to achieve this, there needs to be a strong equity focus from public authorities and an active participation in areas of interests.

In first place, private activity needs to be regulated, as companies do not respond to equity goals but to economic profits. This is the case of micro-mobility operators as described in this work, in which their operation should be incentivized or restricted to align with equity goals in the public agenda.

At the same time, inequality should be measured explicitly through diverse indicators to include minorities and disfavoured groups in the conversation. Impacts of policies on improving accessibility – a representation of opportunities available – and diminishing inequality cannot be assessed if they are not measured in the first place. If a major objective of transport is to provide high levels of accessibility, then it would be logical that accessibility measures should be further developed to play a more important role in transport analysis and planning.

Ethics-driven theories such as egalitarianism, sufficientarianism and vertical equity are concepts that complement each other – and do not compete – as they all promote equity and thus, provide decision makers with a justifiable and defensible policy approach. Vertical equity requires that disadvantaged people be identified and given special consideration in planning, to ensure that they are not made worse off, and that their needs are accommodated. This refers to, as seen in this work, the allocation of

resources to given areas and the specific needs of the population living in these areas according to their demographic characteristics. This process should be continuous as inequality is a dynamic phenomenon in which needs evolve and limits change over time.

Some of the solutions presented complemented public transport delivering first-mile and last-mile trips and introducing the concept of micro-transit. New mobility solutions can help cities make progress towards transportation equity goals, especially strengthening the public-private partnership and leveraging data and technology to evaluate progress. Developing policies to incentivize the equitable placement of vehicles is becoming easier to monitor and reward. Through emerging data-sharing requirements that are part of new mobility operating permits, cities can access new data to evaluate the availability and use of services such as shared bikes, scooters, and cars in traditionally underserved areas.

At the same time, it is important to highlight that micro-mobility complements and does not replace public transport, so it should not be thought of it as a threat. Small, shared vehicles serve as a tool to support the main public transport network and cover a larger served area. This ultimately increases accessibility for the areas involved, but it is only designed as first and last mile solutions so has limited range, in comparison to the characteristic high speed and long distances of metro, rail and bus.

Providing improved first and last-mile connectivity is not only beneficial to passengers but also to transport operators. For rail, studies have found that improved first and last-mile station connectivity is more effective at increasing ridership than speeding up the railway, expanding the railway, or providing better service reliability. Put simply, rail and micromobility are naturally complementary: rail transport covers great distances at high speeds, but with limited flexibility running on fixed routes and timetables. Micromobility is limited in practical range but is highly flexible in terms of trip destination, route choice and timing.

Eventually, the accessibility indicator used in this work can be improved in different ways. A more complex and precise analysis should include the level of service of transport, considering routes, destinations, speed, frequency, schedules, etc. It would be interesting to explore accessibility as a broader consideration and measure ease of access, ease of information, wheelchair access, etc. Thresholds of sufficientarianism might apply differently in each city or region being considered. In this sense, new forms of inequality, including traditional economic indicators can be included in the analysis. Finally, the performance of public transport could be measured against other modes to compare indicators of inclusion, affordability and so on.

Hopefully, this work will serve as inspiration and as a guideline for researchers and policy-makers to measure and plan for equitable transportation in cities around the world.

8

BIBLIOGRAPHY AND REFERENCES

8.1 BIBLIOGRAPHY

Afonso, H. *et al* (2015). *Concepts of Inequality.* Development Issues No. 1. United Nations.

Banister, D. (2018). *Inequality in Transport*. Alexandrine Press, Marcham.

Citilabs Inc. (2016). *Multi-modal Accessibility Methodology and Application.* Retrieved from: https://www.citilabs.com/software/

ITF, OECD (2019). *Benchmarking Accessibility in Cities: Measuring the Impact of Proximity and Transport Performance*. International Transport Forum Policy Papers, No. 68. OECD Publishing, Paris.

Järv, O. *et al* (2018). *Dynamic cities: Location-based accessibility modelling as a function of time*. Applied Geography,Volume 95. University of Helsinki, Helsinki.

Litman, T. (2002). *Evaluating Transportation Equity*. World Transport Policy & Practice Volume 8.

Litman, T. (2014). *Evaluating Public Transit Benefits and Costs.* Victoria Transport Policy Institute.

Litman, T. (2020). *Evaluating Transportation Equity: Guidance for Incorporating Distributional Impacts in Transportation Planning*. Victoria Transport Policy Institute.

Lucas, K. (2004). *Running on Empty: Transport, Social Exclusion and Environmental Justice*. Bristol University Press, Bristol.

Lucas, K. *et al* (2016). *A method to evaluate equitable accessibility: combining ethical theories and accessibility-based approaches*. Transportation 43, 473–490.

Martens, K. (2006). *Basing Transport Planning on Principles of Social Justice*. Berkeley Planning Journal Volume 19, Berkeley.

Miller, E. (2020). *Measuring Accessibility Methods and Issues*. International Transport Forum Discussion Papers, No. 2020/25, OECD Publishing, Paris.

Momentum Transport Consultancy (2021). *Investing in Micromobility at Stations. A London Study of Benefits and Design Options.* London School of Economics and Political Science, London.

National Association of City Transportation Officials (2018). *Guidelines for the Regulation and Management of Shared Active Transportation*. NACTO Publications, New York.

Ortúzar, J., Willumsen, L. (2011). *Modelling Transport.* Wiley, Chichester, UK.

Oviedo Hernández, D. *et al*. (2014). *Transport and Poverty: A review of the evidence*. University College of London.

Peralta Quiros, T. *et al* (2019). *Exploring Accessibility to Employment Opportunities in African Cities: A First Benchmark.* Policy Research Working Papers, No. 8971, World Bank, Washington DC.

Populus Technologies, Inc. (2018). *Measuring Equitable Access to New Mobility: A Case Study of Shared Bikes and Electric Scooters.* Retrieved from: www.populus.ai/publications

Populus Technologies, Inc. (2020). *Curb and Mobility Management: The Role of Pricing, Incentives, and Data for Improving Curbside Utilization.* Retrieved from: www.populus.ai/publications

Rawls, J. (1971). *A Theory of Justice*. The Belknap Press of Harvard University Press, Cambridge.

Remix, Inc. (2018). *Micromobility's opportunity to serve the underserved edges*. Retrieved from: https://www.remix.com/resource-library

Shields, L. (2020). *Sufficientarianism.* Philosophy Compass by John Wiley & Sons Ltd, Manchester.

Shunhua B., Junfeng J. (2020). *Dockless E-scooter usage patterns and urban built Environments: A comparison study of Austin, TX, and Minneapolis, MN*. Urban Information Lab, The School of Architecture, University of Texas, Austin.

Silva, C., Oliveira, V. (2018). Acessibilidade. In, *Planeamento Urbano*: *investigação, ensino e prática profissional*. Edições Afrontamento.

Vaccaro Rivera, L. (2011). *Análisis de la accesibilidad desde la perspectiva de la movilidad.* Universidad de Chile, Santiago.

Vianova, Inc. (2020). *European Policy Guidelines on Shared Micro-Mobility*. Retrieved from: https://www.vianova.io/resources-library/#white-papers

Walker, J. (2012). *Human Transit: How Clearer Thinking about Public Transit Can Enrich Our Communities and Our Lives.* Island Press, Washington DC.

8.1 WEBSITE REFERENCES

https://www.fastcompany.com/90568413/scooters-are-badly-designed-and-increase-inequality-heres-how-to-fix-them (Accessed on 01/11/2020)

https://www.fastcompany.com/90563920/this-map-tells-you-if-you-live-in-a-15-minute-city (Accessed on 01/11/2020)

https://www.washingtonpost.com/technology/2019/03/12/scooters-are-littering-sidewalks-injuring-pedestrians-can-this-startup-bring-order-chaos/ (Accessed on 12/02/2021)

https://www.bbc.com/news/uk-53219331 (Accessed on 10/10/2020)

https://www.thebulletin.be/scooters-causing-problems-pedestrians-disabilities (Accessed on 10/10/2020)

https://issuu.com/cite7/docs/tt40.2-summer2018/24 (Accessed on 21/03/2021)

https://www.open-accessibility.org/versions/ (Accessed on 12/10/2020)

http://www.oecd.org/inequality.htm (Accessed on 08/10/2020)

https://betterbikeshare.org/2019/03/21/e-scooters-equity-and-accessibility/ (Accessed on 12/03/2021)

https://citylimits.org/2019/05/14/opinion-the-equity-case-for-e-bikes-e-scooters/ (Accessed on 21/03/2021)

https://escooterrider.com/are-electric-scooters-faster-than-bicycles/ (Accessed on 06/04/2021)

https://www.theglobeandmail.com/canada/article-bikes-pedestrians-and-the-15-minute-city-how-the-pandemic-is/ (Accessed on 16/07/2021)

9

ANNEX

9.1 DEMOGRAPHIC INFORMATION FOR PORTO CIVIL PARISHES

County	Civil Parish	Residents	Male Residents	Female Residents	0 - 13 Age Group	14 - 19 Age Group	20 - 64 Age Group	65+ Age Group
Gondomar		1505	730	775	193	109	888	315
Gondomar	Rio Tinto	50713	23921	26792	7081	3202	32391	8039
Gondomar	Baguim do Monte (Rio Tinto)	14102	6762	7340	2084	912	9158	1948
Gondomar	União das freguesias de Fânzeres e São Pedro da Cova	39586	19387	20199	6033	2789	25417	5347
Gondomar	União das freguesias de Foz do Sousa e Covelo	7701	3788	3913	944	485	4951	1321
Gondomar	União das freguesias de Gondomar (São Cosme), Valbom e Jovim	48600	23494	25106	6918	3195	31136	7351
Gondomar	União das freguesias de Melres e Medas	5820	2925	2895	770	447	3754	849
Maia	Águas Santas	27470	13110	14360	4508	1710	17798	3454
Maia	Folgosa	3704	1833	1871	550	277	2320	557
Maia	Milheirós	4861	2350	2511	774	318	3126	643
Maia	Moreira	12890	6248	6642	2159	714	8341	1676
Maia	São Pedro Fins	1837	901	936	286	126	1160	265
Maia	Vila Nova da Telha	5886	2839	3047	897	384	3759	846
Maia	Pedrouços	12149	5697	6452	1639	718	7663	2129
Maia	Castêlo da Maia	18395	8896	9499	2898	1123	12071	2303
Maia	Cidade da Maia	40134	19153	20981	6154	2466	26275	5239

Maia	Nogueira e Silva Escura	7980	3828	4152	1438	474	5072	996
Matosinhos	União das freguesias de Custóias, Leça do Balio e Guifões	45716	22261	23455	6184	2879	29236	7417
Matosinhos	União das freguesias de Matosinhos e Leça da Palmeira	49486	23145	26341	6771	2942	31457	8316
Matosinhos	União das freguesias de Perafita, Lavra e Santa Cruz do Bispo	29407	14278	15129	4027	1784	19061	4535
Matosinhos	União das freguesias de São Mamede de Infesta e Senhora da Hora	50869	23760	27109	6424	3196	33232	8017
Porto	Bonfim	24265	10674	13591	2268	1349	14064	6584
Porto	Campanhã	32659	15130	17529	3681	2159	19295	7524
Porto	Paranhos	44298	20045	24253	4393	2463	26946	10496
Porto	Ramalde	38012	17311	20701	5025	2426	23144	7417
Porto	União das freguesias de Aldoar, Foz do Douro e Nevogilde	28858	13438	15420	3673	1926	17069	6190
Porto	União das freguesias de Cedofeita, Santo Ildefonso, Sé, Miragaia, São Nicolau e Vitória	40440	18081	22359	3577	1907	24102	10854
Porto	União das freguesias de Lordelo do Ouro e Massarelos	29059	13425	15634	3588	1839	17614	6018
Póvoa de Varzim	Balazar	2543	1194	1349	432	188	1582	341
Póvoa de Varzim	Estela	2316	1123	1193	396	190	1385	345
Póvoa de Varzim	Laundos	2055	976	1079	339	165	1296	255
Póvoa de Varzim	Rates	2505	1234	1271	418	190	1557	340
Póvoa de Varzim	União das freguesias de Aver-o-Mar, Amorim e Terroso	13987	6678	7309	2207	1086	8798	1896
Póvoa de Varzim	União das freguesias de Aguçadoura e Navais	5736	2748	2988	898	429	3542	867
Póvoa de Varzim	União das freguesias da Póvoa de Varzim, Beiriz e Argivai	34266	16005	18261	4977	2464	21377	5448
Valongo	Alfena	15211	7372	7839	2413	1055	9709	2034
Valongo	Ermesinde	38798	18358	20440	5340	2477	24860	6121
Valongo	Valongo	23925	11486	12439	4235	1509	15810	2371
Valongo	União das freguesias de Campo e Sobrado	30652	14748	15904	5270	2036	20079	3267
Vila do Conde	Árvore	5196	2609	2587	863	341	3285	707
Vila do Conde	Aveleda	1314	633	681	149	70	839	256
Vila do Conde	Azurara	2305	1091	1214	344	146	1509	306
Vila do Conde	Fajozes	1425	699	726	193	93	893	246

Vila do Conde	Gião	1756	877	879	260	115	1120	261
Vila do Conde	Guilhabreu	2357	1154	1203	315	158	1527	357
Vila do Conde	Junqueira	2019	977	1042	296	151	1251	321
Vila do Conde	Labruge	2806	1372	1434	390	144	1813	459
Vila do Conde	Macieira da Maia	2321	1138	1183	428	169	1461	263
Vila do Conde	Mindelo	3491	1646	1845	475	234	2202	580
Vila do Conde	Modivas	1806	873	933	228	105	1160	313
Vila do Conde	Vila Chã	3094	1473	1621	452	223	1917	502
Vila do Conde	Vila do Conde	28636	13730	14906	4466	2028	18276	3866
Vila do Conde	Vilar de Pinheiro	2537	1233	1304	336	166	1583	452
Vila do Conde	União das freguesias de Bagunte, Ferreiró, Outeiro Maior e Parada	2848	1404	1444	441	204	1753	450
Vila do Conde	União das freguesias de Fornelo e Vairão	2643	1261	1382	396	170	1656	421
Vila do Conde	União das freguesias de Malta e Canidelo	2291	1121	1170	353	161	1465	312
Vila do Conde	União das freguesias de Retorta e Tougues	2052	1000	1052	326	149	1317	260
Vila do Conde	União das freguesias de Rio Mau e Arcos	2681	1293	1388	420	220	1642	399
Vila do Conde	União das freguesias de Touguinha e Touguinhó	3386	1633	1753	564	228	2154	440
Vila do Conde	União das freguesias de Vilar e Mosteiró	2569	1252	1317	324	161	1558	526
Vila Nova de Gaia	Arcozelo	14352	6937	7415	2185	860	9123	2184
Vila Nova de Gaia	Avintes	11497	5603	5894	1606	779	7256	1856
Vila Nova de Gaia	Canelas	13459	6525	6934	2229	911	8849	1470
Vila Nova de Gaia	Canidelo	27769	13362	14407	4228	1725	18250	3566
Vila Nova de Gaia	Madalena	10040	4789	5251	1421	536	6316	1767
Vila Nova de Gaia	Oliveira do Douro	22383	10651	11732	3094	1461	14191	3637
Vila Nova de Gaia	São Félix da Marinha	12706	6144	6562	1938	727	8156	1885
Vila Nova de Gaia	Vilar de Andorinho	18155	8820	9335	2922	1436	11738	2059
Vila Nova de Gaia	União das freguesias de Grijó e Sermonde	11938	5770	6168	1842	837	7410	1849
Vila Nova de Gaia	União das freguesias de Gulpilhares e Valadares	22019	10504	11515	3508	1258	13834	3419
Vila Nova de Gaia	União das freguesias de Mafamude e Vilar do Paraíso	52422	24386	28036	6697	3221	33268	9236
Vila Nova de Gaia	União das freguesias de Pedroso e Seixezelo	20426	9979	10447	2910	1430	13036	3050

Vila Nova de Gaia	União das freguesias de Sandim, Olival, Lever e Crestuma	17165	8311	8854	2409	1205	10808	2743
Vila Nova de Gaia	União das freguesias de Santa Marinha e São Pedro da Afurada	33714	15791	17923	4325	2050	21604	5735
Vila Nova de Gaia	União das freguesias de Serzedo e Perosinho	14250	6918	7332	2099	969	8980	2202

9.2 ACCESSIBILITY INFORMATION FOR PORTO CIVIL PARISHES

Civil Parish	Population reached with each isodistance for metro and train								Accessible population for each isodistance								Min Isodistance for 100% accessible population
	1000m metro	3000m metro	5000m metro	10000m metro	1000m train	3000m train	5000m train	10000m train	1000m metro	3000m metro	5000m metro	10000m metro	1000m train	3000m train	5000m train	10000m train	
Lomba	0	0	0	0	0	0	0	0	0%	0%	0%	0%	0%	0%	0%	0%	Not Accessible
Rio Tinto	30755	50713	50713	50713	13422	50510	50713	50713	61%	100%	100%	100%	26%	100%	100%	100%	3000
Baguim do Monte (Rio Tinto)	5637	14102	14102	14102	1444	14071	14102	14102	40%	100%	100%	100%	10%	100%	100%	100%	3000
União das freguesias de Fânzeres e São Pedro da Cova	4658	25345	36331	39586	0	9443	30820	39586	12%	64%	92%	100%	0%	24%	78%	100%	10000
União das freguesias de Foz do Sousa e Covelo	0	0	0	3450	0	0	0	3423	0%	0%	0%	45%	0%	0%	0%	44%	Not Accessible
União das freguesias de Gondomar (São Cosme), Valbom e Jovim	0	12389	37006	48600	0	4961	23177	48600	0%	25%	76%	100%	0%	10%	48%	100%	10000
União das freguesias de Melres e Medas	0	0	0	0	0	0	0	316	0%	0%	0%	0%	0%	0%	0%	5%	Not Accessible
Águas Santas	0	9457	26256	27470	6000	23501	27470	27470	0%	34%	96%	100%	22%	86%	100%	100%	5000
Folgosa	0	0	12	3704	1008	3441	3704	3704	0%	0%	0%	100%	27%	93%	100%	100%	5000
Milheirós	0	13	4813	4861	0	1495	4861	4861	0%	0%	99%	100%	0%	31%	100%	100%	5000
Moreira	6564	12890	12890	12890	0	0	0	9387	51%	100%	100%	100%	0%	0%	0%	73%	3000
São Pedro Fins	0	0	56	1837	1117	1837	1837	1837	0%	0%	3%	100%	61%	100%	100%	100%	3000
Vila Nova da Telha	5586	5886	5886	5886	0	0	0	457	95%	100%	100%	100%	0%	0%	0%	8%	3000

Pedrouços	919	12149	12149	12149	0	8065	12149	12149	8%	100%	100%	100%	0%	66%	100%	100%	3000
Castêlo da Maia	7567	18388	18395	18395	0	151	5733	18395	41%	100%	100%	100%	0%	1%	31%	100%	5000
Cidade da Maia	13269	38800	40134	40134	0	0	4357	40134	33%	97%	100%	100%	0%	0%	11%	100%	5000
Nogueira e Silva Escura	0	1614	7980	7980	0	4093	7980	7980	0%	20%	100%	100%	0%	51%	100%	100%	5000
União das freguesias de Custóias, Leça do Balio e Guifões	19571	45348	45716	45716	0	0	0	45716	43%	99%	100%	100%	0%	0%	0%	100%	5000
União das freguesias de Matosinhos e Leça da Palmeira	31858	49374	49486	49486	0	0	0	36278	64%	100%	100%	100%	0%	0%	0%	73%	5000
União das freguesias de Perafita, Lavra e Santa Cruz do Bispo	668	14611	26088	29407	0	0	0	1240	2%	50%	89%	100%	0%	0%	0%	4%	10000
União das freguesias de São Mamede de Infesta e Senhora da Hora	25967	50869	50869	50869	0	0	15862	50869	51%	100%	100%	100%	0%	0%	31%	100%	3000
Bonfim	24265	24265	24265	24265	5100	24265	24265	24265	100%	100%	100%	100%	21%	100%	100%	100%	1000
Campanhã	23821	32659	32659	32659	3471	31453	32659	32659	73%	100%	100%	100%	11%	96%	100%	100%	3000
Paranhos	26842	44298	44298	44298	0	28924	44298	44298	61%	100%	100%	100%	0%	65%	100%	100%	3000
Ramalde	23341	38012	38012	38012	0	2860	33410	38012	61%	100%	100%	100%	0%	8%	88%	100%	3000
União das freguesias de Aldoar, Foz do Douro e Nevogilde	3034	21317	28858	28858	0	0	3343	28858	11%	74%	100%	100%	0%	0%	12%	100%	5000
União das freguesias de Cedofeita, Santo Ildefonso, Sé, Miragaia, São Nicolau e Vitória	40440	40440	40440	40440	15781	40440	40440	40440	100%	100%	100%	100%	39%	100%	100%	100%	1000
União das freguesias de Lordelo do Ouro e Massarelos	4686	29059	29059	29059	0	7921	28200	29059	16%	100%	100%	100%	0%	27%	97%	100%	3000
Balazar	0	0	0	78	0	0	0	1203	0%	0%	0%	3%	0%	0%	0%	47%	Not Accessible
Estela	0	0	0	2281	0	0	0	0	0%	0%	0%	98%	0%	0%	0%	0%	Not Accessible
Laundos	0	0	0	2055	0	0	0	0	0%	0%	0%	100%	0%	0%	0%	0%	10000
Rates	0	0	0	1137	0	0	0	0	0%	0%	0%	45%	0%	0%	0%	0%	Not Accessible
União das freguesias de Aver-o-Mar, Amorim e Terroso	0	6800	12871	13987	0	0	0	0	0%	49%	92%	100%	0%	0%	0%	0%	10000

União das freguesias de Aguçadoura e Navais	0	0	750	5736	0	0	0	0	0%	0%	13%	100%	0%	0%	0%	0%	10000
União das freguesias da Póvoa de Varzim, Beiriz e Argivai	20788	31669	34266	34266	0	0	0	0	61%	92%	100%	100%	0%	0%	0%	0%	5000
Alfena	0	0	1390	15211	2894	13720	15211	15211	0%	0%	9%	100%	19%	90%	100%	100%	5000
Ermesinde	0	4008	34751	38798	28020	38798	38798	38798	0%	10%	90%	100%	72%	100%	100%	100%	3000
Valongo	0	635	17891	23925	15557	23925	23925	23925	0%	3%	75%	100%	65%	100%	100%	100%	3000
União das freguesias de Campo e Sobrado	0	0	0	13875	3012	9668	13635	15924	0%	0%	0%	45%	10%	32%	44%	52%	Not Accessible
Árvore	3843	5196	5196	5196	0	0	0	0	74%	100%	100%	100%	0%	0%	0%	0%	3000
Aveleda	424	1314	1314	1314	0	0	0	0	32%	100%	100%	100%	0%	0%	0%	0%	3000
Azurara	2186	2305	2305	2305	0	0	0	0	95%	100%	100%	100%	0%	0%	0%	0%	3000
Fajozes	582	1425	1425	1425	0	0	0	0	41%	100%	100%	100%	0%	0%	0%	0%	3000
Gião	0	848	1756	1756	0	0	0	0	0%	48%	100%	100%	0%	0%	0%	0%	5000
Guilhabreu	0	135	2357	2357	0	0	0	2357	0%	6%	100%	100%	0%	0%	0%	100%	5000
Junqueira	0	0	311	2019	0	0	0	0	0%	0%	15%	100%	0%	0%	0%	0%	10000
Labruge	316	1562	2806	2806	0	0	0	0	11%	56%	100%	100%	0%	0%	0%	0%	5000
Macieira da Maia	0	37	1463	2321	0	0	0	260	0%	2%	63%	100%	0%	0%	0%	11%	10000
Mindelo	1612	3491	3491	3491	0	0	0	0	46%	100%	100%	100%	0%	0%	0%	0%	3000
Modivas	1178	1806	1806	1806	0	0	0	0	65%	100%	100%	100%	0%	0%	0%	0%	3000
Vila Chã	268	2999	3094	3094	0	0	0	0	9%	97%	100%	100%	0%	0%	0%	0%	5000
Vila do Conde	22637	28636	28636	28636	0	0	0	0	79%	100%	100%	100%	0%	0%	0%	0%	3000
Vilar de Pinheiro	677	2537	2537	2537	0	0	0	464	27%	100%	100%	100%	0%	0%	0%	18%	3000
União das freguesias de Bagunte, Ferreiró, Outeiro Maior e Parada	0	0	152	2691	0	0	0	1119	0%	0%	5%	94%	0%	0%	0%	39%	Not Accessible
União das freguesias de Fornelo e Vairão	0	7	960	2643	0	0	0	1400	0%	0%	36%	100%	0%	0%	0%	53%	10000
União das freguesias de Malta e Canidelo	0	189	1595	2291	0	0	0	755	0%	8%	70%	100%	0%	0%	0%	33%	10000
União das freguesias de Retorta e Tougues	344	1549	2052	2052	0	0	0	0	17%	75%	100%	100%	0%	0%	0%	0%	5000
União das freguesias de Rio Mau e Arcos	0	0	0	2681	0	0	0	0	0%	0%	0%	100%	0%	0%	0%	0%	10000

União das freguesias de Touguinha e Touguinhó	0	1986	3386	3386	0	0	0	0	0%	59%	100%	100%	0%	0%	0%	0%	5000
União das freguesias de Vilar e Mosteiró	310	2524	2569	2569	0	0	0	193	12%	98%	100%	100%	0%	0%	0%	8%	5000
Arcozelo	0	0	0	14325	6296	14274	14352	14352	0%	0%	0%	100%	44%	99%	100%	100%	5000
Avintes	0	0	4303	11497	0	0	1233	11497	0%	0%	37%	100%	0%	0%	11%	100%	10000
Canelas	0	2691	10727	13459	0	647	13200	13459	0%	20%	80%	100%	0%	5%	98%	100%	10000
Canidelo	0	2233	25297	27769	5924	27499	27769	27769	0%	8%	91%	100%	21%	99%	100%	100%	5000
Madalena	0	1691	8674	10040	6151	10040	10040	10040	0%	17%	86%	100%	61%	100%	100%	100%	3000
Oliveira do Douro	2259	21592	22383	22383	231	14644	22383	22383	10%	96%	100%	100%	1%	65%	100%	100%	5000
São Félix da Marinha	0	0	0	4335	2190	11786	12706	12706	0%	0%	0%	34%	17%	93%	100%	100%	5000
Vilar de Andorinho	0	12490	18155	18155	0	0	13317	18155	0%	69%	100%	100%	0%	0%	73%	100%	5000
União das freguesias de Grijó e Sermonde	0	0	0	3485	0	0	2825	11938	0%	0%	0%	29%	0%	0%	24%	100%	10000
União das freguesias de Gulpilhares e Valadares	0	2202	12965	22019	13982	21039	22019	22019	0%	10%	59%	100%	63%	96%	100%	100%	5000
União das freguesias de Mafamude e Vilar do Paraíso	32583	51424	52422	52422	7404	47552	52422	52422	62%	98%	100%	100%	14%	91%	100%	100%	5000
União das freguesias de Pedroso e Seixezelo	0	201	3081	18884	0	0	1894	20318	0%	1%	15%	92%	0%	0%	9%	99%	Not Accessible
União das freguesias de Sandim, Olival, Lever e Crestuma	0	0	0	2325	0	0	0	8474	0%	0%	0%	14%	0%	0%	0%	49%	Not Accessible
União das freguesias de Santa Marinha e São Pedro da Afurada	6997	31410	33714	33714	20821	33714	33714	33714	21%	93%	100%	100%	62%	100%	100%	100%	3000
União das freguesias de Serzedo e Perosinho	0	0	0	14250	0	1477	9566	14250	0%	0%	0%	100%	0%	10%	67%	100%	10000

9.3 MAP OF PORTO METRO NETWORK

9.4 MAP OF PORTO RAIL NETWORK