*Journal of Regional and City Planning*
vol. 35, no. 1, page. 1-20, April 2024
DOI: 10.5614/jpwk.2024.35.1.1

# Examining the Impact of Different Street Classification Scenarios on Active Transportation Equity. Insights from Athens, Greece

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[Received: 8 August 2023; 1st revision: 28 November 2023; 2nd revision: 29 December 2023; accepted in final version: 11 January 2024]

***Abstract***. *Transport equity is an essential characteristic of a just city and a concept related to social inclusion. This study examined how different street classification scenarios will affect active transportation equity. Four different scenarios with different planning rationales were developed that reformulate the street classification in a municipality within a metropolitan area, i.e., Kallithea in Athens, Greece. These scenarios give rise to new street categories that reallocate street space favoring active transport users. The evaluation of active transportation equity was carried out by utilizing spatial analysis and welfare economics through the lens of egalitarian and sufficientarian approaches. Based on the results, scenarios that propose new urban centers as well as a readable street classification with traffic calming zones determined by ring roads seem to be more efficient in accommodating vulnerable users in an equitable way. Hence, new planning schemes should rely on active modes, leaving automobiles behind. In general, measuring the impact of street classification scenarios through the lens of equity is critical for improving the quality of life in cities. Additionally, it is noteworthy knowledge for policy makers, planners, and local administrators. Finally, this research may inspire new studies, enriching the scientific debate.*

***Keywords***. *Athens, active transportation equity, integrated mobility scenarios, street classification, vulnerable road users.*

***Abstrak***. *Keadilan transportasi merupakan karakteristik penting dari kota yang berkeadilan dan sebuah konsep yang berkaitan dengan inklusi sosial. Studi ini mengkaji bagaimana skenario klasifikasi jalan yang berbeda akan mempengaruhi ekuitas transportasi aktif. Empat skenario berbeda dengan alasan perencanaan berbeda dikembangkan untuk merumuskan kembali klasifikasi jalan di suatu kotamadya dalam wilayah metropolitan, yaitu Kallithea di Athena, Yunani. Skenario ini memunculkan kategori jalan baru yang merealokasi ruang jalan untuk mendukung pengguna transportasi aktif. Evaluasi pemerataan transportasi aktif dilakukan dengan memanfaatkan analisis spasial dan ekonomi kesejahteraan melalui kacamata pendekatan egaliter dan kecukupan. Berdasarkan hasil tersebut, skenario yang mengusulkan pusat perkotaan baru serta klasifikasi jalan yang mudah dibaca dengan zona tenang lalu lintas yang ditentukan oleh jalan lingkar tampaknya lebih efisien dalam mengakomodasi pengguna yang rentan secara adil. Oleh karena itu, skema perencanaan baru harus mengandalkan moda aktif, dan tidak lagi menggunakan mobil. Secara umum, mengukur dampak skenario klasifikasi jalan melalui kacamata keadilan sangat penting untuk meningkatkan kualitas hidup di perkotaan. Selain itu, pengetahuan ini juga penting bagi para pembuat kebijakan, perencana, dan administrator lokal.*

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*Pada akhirnya, penelitian ini dapat menginspirasi penelitian-penelitian baru, memperkaya perdebatan ilmiah.*

***Kata kunci***. *Athena, kesetaraan transportasi aktif, klasifikasi jalan, pengguna jalan yang rentan, skenario mobilitas terintegrasi,.*

## Introduction

Cities are complex social, political, and cultural entities (Lefebvre, 1996) that constantly change (Harvey, 2012). One crucial factor influencing urban form and how cities function is mobility (Docherty and Shaw, 2019). Hence, transport systems should be clearly organized, operating under rigorous objectives. In this context, adopting a holistic approach of integrated urban mobility planning scenarios incorporating both transport and land uses would be a game changer. One of the most important tools in favor of integrated planning is street classification or road network hierarchy (Huang et al., 2016). Roads and streets can be categorized into classes depending on the role they play (Ribeiro, 2012). Additionally, street classification also determines the role of each transport mode. According to many studies (e.g., Jones et al., 2008; Stamatiadis et al., 2023; Tsigdinos and Vlastos, 2021), street classification schemes should embrace sustainable mobility principles, recognizing streets as complex and multimodal features and therefore promote a new mobility culture. This planning rationale, inspired by environmental awareness, societal change, and economic efficiency, will transform car-oriented arterials into multimodal corridors, establish traffic calming areas, and truly enhance active transport modes (Tsigdinos et al., 2020). Moreover, these street classification approaches put active transport modes (walking and cycling) at the forefront. For instance, pedestrian-friendly solutions like pedestrian malls emerge, thus appraising accessibility and comfortability in the public street space (Ismael et al., 2019). What is more, street classification is a major tool for creating neighborhoods that potentially could form 15-minute cities. The concept of a 15-minute city describes a novel perspective of 'chrono-urbanism', where proximity and diversity are appreciated (Moreno et al., 2021; Pozoukidou and Chatziyiannaki, 2021). Notably, urban mobility scenarios that re-think street classification in urban areas may have critical effects on the equity of transport systems.

Transport equity is defined by Martens (2016) as "the minimum level of access to certain key activities by anyone". In general, the concept of transport equity refers to equal access to several facilities (e.g., schools, cultural centers, shops, administration, etc.) and infrastructure (e.g., public transport lines, pedestrian streets, traffic calming streets, cycling lanes, etc.), which are necessary for an adequate level of quality of life (Sugiyantoro, 2001; Vasconcellos, 2014; Arellana et al., 2021). Absence of access to key activities could lead to insufficient participation in social and economic life of communities, thus nurturing conditions of social exclusion (Titheridge et al., 2009; van Wee et al., 2012). In general, equity is discussed in the literature through several lenses. Utilitarianism, libertarianism, intuitionism, egalitarianism, and capability approaches are different approaches to equity, identifying different critical issues and outlining different aims (Pereira et al., 2017). It is underlined that the results of these approaches differ, signifying that each approach should be carefully chosen to ensure trustworthy findings at the end (Nahmias-Biran et al., 2017). None of them is dominant, but each has strong points and weaknesses. Therefore, the context and the scope of analysis matter (Pereira and Karner, 2021).

Moreover, equity is not about one and only transport mode, but it can cover a broad spectrum of modes encountered in cities, thus formulating various aspects (e.g., public transport, car, active modes, etc.). Among these various aspects of transport equity, active transportation equity recently has received considerable interest (Lee et al., 2016). Notable previous works are those of Mora et al. (2021) and Pritchard et al. (2019), who investigated different cycling infrastructure scenarios and both drew intriguing conclusions. Tellingly, although accessibility indicators showed an improvement, transport equity conditions remained elusive. This should ignite a debate about how transport scenarios can achieve truly equitable conditions. Nevertheless, despite the particular importance of transport equity to urban communities (Shi and Zhou, 2012), the current literature, compared to other tools of evaluation, is still limited (van Wee, 2016). Especially, if focus falls on how integrated urban mobility scenarios and rethinking street classification influence (active transportation) equity, then it should be stressed that the literature is still premature, manifesting the need for more relevant studies.

In this context, this study examined how different integrated urban mobility scenarios might affect transport equity and particularly active transportation equity, i.e., the opportunity of vulnerable users like pedestrians, people with disabilities or cyclists (Tzouras et al., 2020) to have fair access to urban road space tailored to their needs. This research was built on an egalitarian approach, hypothesizing that every neighborhood in the study area should have equal access to active-mode infrastructure and especially to roads devoted to vulnerable road users, depending on the population. Additionally, with the aim to obtain a holistic view of the issue, it also adopted a sufficientarian approach (see also Martens, 2016), trying to identify if the area has fair access to streets, prioritizing active modes.

Within this framework, this paper presents four different scenarios with different planning rationales that reformulate the street classification in a municipality within a metropolitan area, i.e., Kallithea in Athens, Greece. These scenarios reflect an integrated nature, employing both urban and transport dimensions and were developed according to a coherent methodology, putting effort both on organizational and spatial aspects. New street categories emerge, reallocating street space to active-mode users. These categories (e.g., shared space, active mobility boulevard, etc.) differentiate from the conventional mobility practice by considering vulnerable users as the centerpiece of the road space (Tzouras et al., 2022). An evaluation carried out by utilizing the well-known measures of Gini index and Lorenz curves, which were calculated for each scenario. Moreover, this research developed a sufficiency index for assessing how active-mode oriented streets are distributed over neighborhoods.

When looking at the contribution of this study, it should be stressed that it is one of the very few that examined how different classification scenarios influence active transportation equity from an egalitarian and sufficientarian perspective. Similar existing literature did not dig into such topics. The majority of existing papers focused on how individual policy measures, interventions and other solutions may affect transport equity, but they do not refer to strategic tools like street classification. This fact reveals a critical research gap. Therefore, this research aimed to fill this gap and open a wide a discussion on the relationship between street classification and equity.

The remainder of this paper is structured as follows: the second section includes the research methodology, displaying the basic steps for building the future scenarios, and what evaluation technique was chosen. The third section briefly describes the study area. The fourth section portrays the results and especially the impacts of the different street classification plans on active transportation equity. The fifth section discusses the results, describing meaningful insights for the present and the future. This section also details some policy recommendations and future research suggestions. Finally, the last section contains our concluding remarks.

## Methodology

The research method consisted of three distinct steps that reflect a hierarchical order. This process is depicted in the following figure (Figure 1):

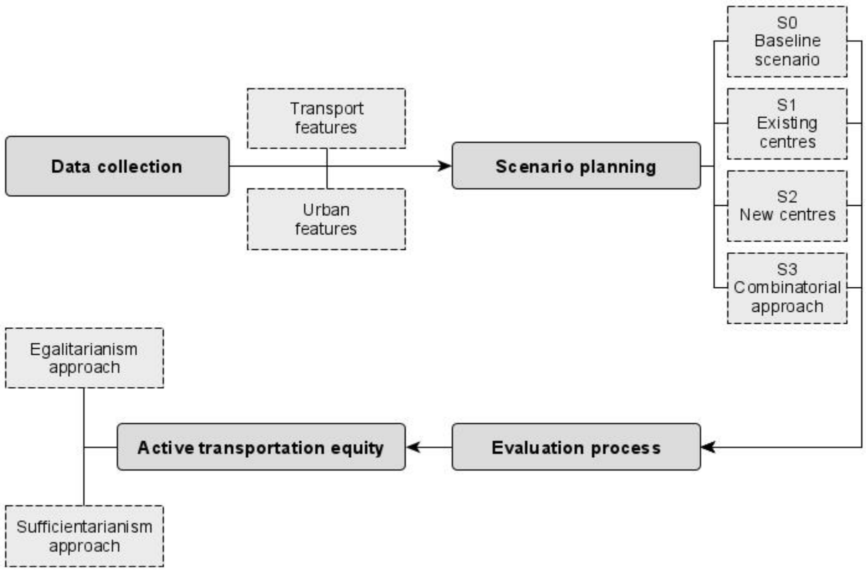


**Figure 1.** Research methodology flow diagram.

The first step includes the collection of data related to the existing conditions (urban and transport characteristics) to identify strengths and weaknesses. Following the data collection, the second step involves the development of different scenarios proposing alternative urban mobility pathways. More specifically, new street classification plans are discussed both organizationally (number and characteristics of street categories) and spatially (actual spatial configuration of categories). Finally, the third step evaluates each scenario considering the impacts on vulnerable users' equity.

*Data collection*

The data collection stage was divided into two parts of equal importance. Notably, all these features do not represent an exhaustive analysis of the existing situation but were tailored to the scope of this research. They were found through a rapid literature review process that focused on which attributes influence street classification under an integrated urban and transport framework. In this context, on the one hand, the first part refers to the urban features, namely: i) land uses (Ismael et al., 2019; Paraskevopoulos and Photis, 2020), ii) natural environment (Telega et al., 2021), and iii) built environment (Ismael et al., 2019; D'Orso and Migliore, 2020). More specifically, land uses are represented by non-residential uses (e.g., shopping, education, recreation, services, etc.) that create higher interaction (and thus human flows) in urban space compared to residential uses (Paraskevopoulos and Photis, 2020). Therefore, they are a suitable proxy for the liveability of streets. Natural environment signifies the existence of parks, squares and in general areas with green or water that may enhance people's feeling and comfort. Built environment in contrast illustrates the quality of buildings along the streets of the study area (architectural landmarks, historical buildings, etc.) that may raise the attractiveness of the street environment. All the above features were obtained from the open data source platform Openstreetmap and were supplemented with on-site observations.

The second part of the data collection stage examined the transport characteristics, namely the following: i) (total) street width (Su et al., 2019), ii) continuity of street network (Tripathy et al., 2021), iii) existing street classification (Tsigdinos and Vlastos, 2021), iv) public transport routes

(Tsigdinos et al., 2020), v) cycling routes (Tsigdinos et al., 2020), and vi) pedestrian or traffic calming streets (Mezoued et al., 2021). Similarly to the urban dimension, the transport features – except from street width, which was calculated based on on-site observation – were obtained from the Openstreetmap platform. All these features were critical for identifying the transport profile of each street segment.

Specifically, the street width factor reflects the distance between the property lines encountered on each street side. It is one of the major transport features, as it displays the availability and the dynamics of each street segment to accommodate different transport modes and types of infrastructure. Moving on, the continuity of the street network portrays the continuous length where geometry remains the same (Tripathy et al., 2021) and is a notable factor for determining main routes either for motorized or active movement. Continuity plays an important role in the readability and the efficiency of street classification systems (Marshall, 2005). The existing street classification is essential in the first stage of the method, as it reflects the current situation on the ground, which the new classification system will rely upon. Recording the current street classification helps recognizing potentials and weaknesses. The remaining features demonstrate the existence of certain infrastructure and services like public transport routes and active mode routes. Active mode infrastructure like cycling corridors (exclusive lanes, tracks, or mixed-used corridors) and pedestrian or shared-space streets should be acknowledged for estimating future needs related to vulnerable groups. Without knowing the existing infrastructure pertaining to pedestrians, cyclists, and people with disabilities at this scale, new street classification scenarios will be detached from the real needs (Tsigdinos et al., 2020).

### *Scenario planning*

The proposed method for building integrated mobility scenarios embodies a spatial planning rationale that perceives urban space as a unified entity, requiring both on-site observation and secondary data to detect the needs of the study area. Therefore, the current condition examination stage should provide a comprehensive background for envisioning alternative street classification pathways. It should be mentioned that this study adopted a two-dimensional approach related to street classification, thus going beyond conventional practices (Jones et al., 2008; Tsigdinos and Vlastos, 2021). These two dimensions were: 1) street significance, and 2) mode priority. Furthermore, regarding the spatial configuration of the new categories, this study utilized geographic information systems (GIS) to translate the scenarios into an actual street classification plan (network analysis tools). Spatial analysis enables objectivity in formulating the network. A conceptual scheme portraying the spatial configuration of each scenario can be found in Figure 2.

Ultimately, four scenarios envisioning different futures were formulated. Three of them were developed via the backcasting approach (Soria-Lara and Banister, 2008), which puts particular emphasis on desirable futures, while the baseline scenario (do nothing) was created by simply forecasting that the existing conditions remain the same. Formulating four scenarios contributes to a broad view of future pathways. The developed scenarios were the following: a) Baseline Scenario – existing conditions regarding street classification remain the same, b) Scenario 1 – new street classification based on existing centers, c) Scenario 2 – new street classification formulating new urban centers, and d) Scenario 3 – new street classification based on existing urban centers, while creating new urban centralities.

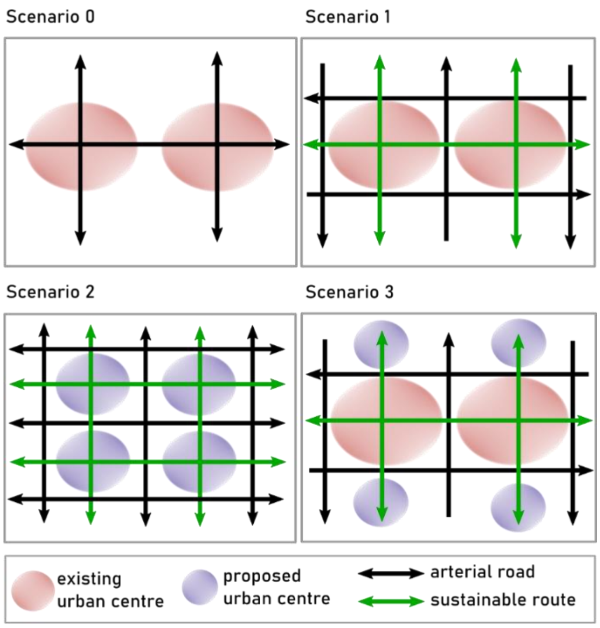


**Figure 2.** Conceptual diagram for the street classification scenarios.

As can be seen from Figure 2, the Baseline Scenario allows through-traffic flows in a car-oriented environment. In contrast, the other scenarios attempt to counteract this unfavorable condition by introducing sustainable routes that prioritize active mobility and public transport. More specifically, Scenario 1 proposes ring roads around existing urban centers that are connected by sustainable routes, Scenario 2 transforms the urban landscape with new urban centers that are protected by ring roads and connected by sustainable routes as well, while Scenario 3 adopts a combinatorial approach, utilizing not only existing centers but also formulating new urban centralities based on the concept of the 15-minute city (Moreno et al., 2021). Tellingly, the backcasting approach results in new scenarios assigning protected and well-connected centers. Moreover, this planning approach scenario proposes new street categories that reflect sustainable mobility principles through adopting certain policy measures, cross-sectional characteristics and interventions.

### *Evaluation process*

#### Measuring equity: egalitarian approach

One of the most popular methods for assessing impacts in terms of equity referring to a specific transport policy or project is using the Lorenz curve and the Gini index (Lucas et al., 2016). The Lorenz curve is a graphical representation of the cumulative percentage of an attribute across the same percentage of a population, ranked from the lowest to the highest level of this attribute (Delbosc and Currie, 2011). When it comes to transportation issues, the attributes can vary; for instance, the x-axis may represent the cumulative distribution of the values of an indicator (e.g., accessibility, pedestrian streets, etc.), whereas the y-axis may indicate the cumulative population or other socioeconomic attributes (van Wee, 2012). In the case of a totally equal distribution, the Lorenz curve takes the form of a 45-degree straight line. The more the Lorenz curve deviates from this straight line, the more the inequality level in the distribution increases (Niehaus et al., 2016).

In this study, the Lorenz curve was used to illustrate the distribution of the length of streets that prioritize active travel (boulevards and local roads) per neighborhood population (population data obtained from the official census). In other words, horizontal equity is in question. Therefore, the developed curves show how each scenario contributes to an equitable condition regarding active mobility across all neighborhoods. This goal is vital, since vulnerable road user infrastructure should be equally distributed in all neighborhoods of a city, with pedestrian- and cycling-friendly conditions (Arellana et al., 2021).

A key component for the creation of the Lorenz curve is the Gini index, which is a numerical summary displaying the overall degree of inequity (Delbosc and Currie, 2011). It takes values from 0 to 1, where the value 0 signifies an equal distribution, while the value 1 signifies an unequal distribution (Guzman et al., 2017). This index is calculated via Equation 1 (Currie and Senbergs, 2007):

$$G = 1 - \sum_{k=1}^{n} (X_k - X_{k-1}) * (Y_k + Y_{k-1}) \quad (1)$$

where

$X_k$: cumulative proportion of the population in neighborhood k
$Y_k$: cumulative proportion of the road length prioritizing active modes in neighborhood k

Therefore, this index and a Lorenz curve were created for each scenario with the aim of detecting the scenario that most contributes to more equitable impacts on vulnerable road users.

## Measuring equity: sufficientarian approach

This research was not only limited to measuring equity across neighborhoods using the Gini index and a Lorenz curve but also sheds light on the sufficiency conditions of the street classification scenarios. Influenced by the sufficientarian approach discussed by several researchers (e.g., Martens, 2016; Lucas et al., 2016; van der Veen et al., 2020), this study defined a simple sufficiency index of active mobility corridors. This index was calculated by dividing the total street length of each neighborhood by the total length of streets prioritizing active modes per neighborhood. According to relevant literature addressing street classification issues (Tsigdinos et al., 2023), the length of roads prioritizing active modes should be either above 50% of the total road length within a neighborhood for full sufficiency, or above 20% for partial sufficiency. These proportions have been found to be in line with sustainable mobility principles and could be a driver for transforming conventional car-oriented cities into climate-friendly and inclusive sustainable-oriented areas. The equation is the following (Equation 2):

$$A_k = \frac{APL_k}{TL_k} \quad (2)$$

where

$A_k$: sufficiency index
$APL_k$: length of streets prioritizing active modes in neighborhood k (in meters)
$TL_k$: total road length in neighborhood k (in meters)

Based on the relevant literature (Tsigdinos et al., 2023), the threshold for accepting a neighborhood as sufficient was set to 0.50 and as partially sufficient to 0.20. In other words, every neighborhood should have at least 20% of streets prioritizing active transport modes to be sufficient in some way, otherwise, it should be called 'non-sufficient'. Notably, to achieve more detailed sufficiency results, one more category was added. The values included in this category lie between 0.80 and 1.00, reflecting perfectly sufficient conditions. Thereupon, Equation 3 is utilized:

$$Neighbourhood = \begin{cases} perfectly\ sufficient, & A_k \geq 0.80 \\ sufficient, & A_k \geq 0.50\ AND\ \ A_k < 0.80 \\ partially\ sufficient, & A_k \geq 0.20\ AND\ \ A_k < 0.50 \\ non-sufficient, & A_k < 0.20 \end{cases} \quad (3)$$

## Study area

The method was applied to the municipality of Kallithea in Athens Metropolitan Area (AMA) in Greece. Kallithea is a suburban municipality next to the seafront with high population density (approx. 250 inhabitants/ha) belonging to the South Sector of Athens. According to the 2021 census (ELSTAT, 2021), the Municipality of Kallithea has a permanent population of 97,616 inhabitants, representing a significant share of the Attica Region (2.56%). It is considered an important municipality in the AMA, neighboring the metropolitan centers of Athens and Piraeus (Mitropoulos et al., 2023). The Urban Plan of the Municipality envisages twenty neighborhoods, depending on the population density. Land use is mixed, including retail, services, recreation, education, sports, health, welfare, etc. The location of Kallithea within AMA is shown in the next figure (Figure 3).

A large municipality was selected because of its urban identity and due to data availability. Tellingly, the existing street classification in the study area is mainly car-oriented, thus neglecting the role of sustainable transport modes (Tsigdinos et al., 2021). However, Kallithea has the potential (high land-use mix, high residential density, low car ownership levels, readable road network structure, etc.) for shifting from conventional to alternative transport modes.

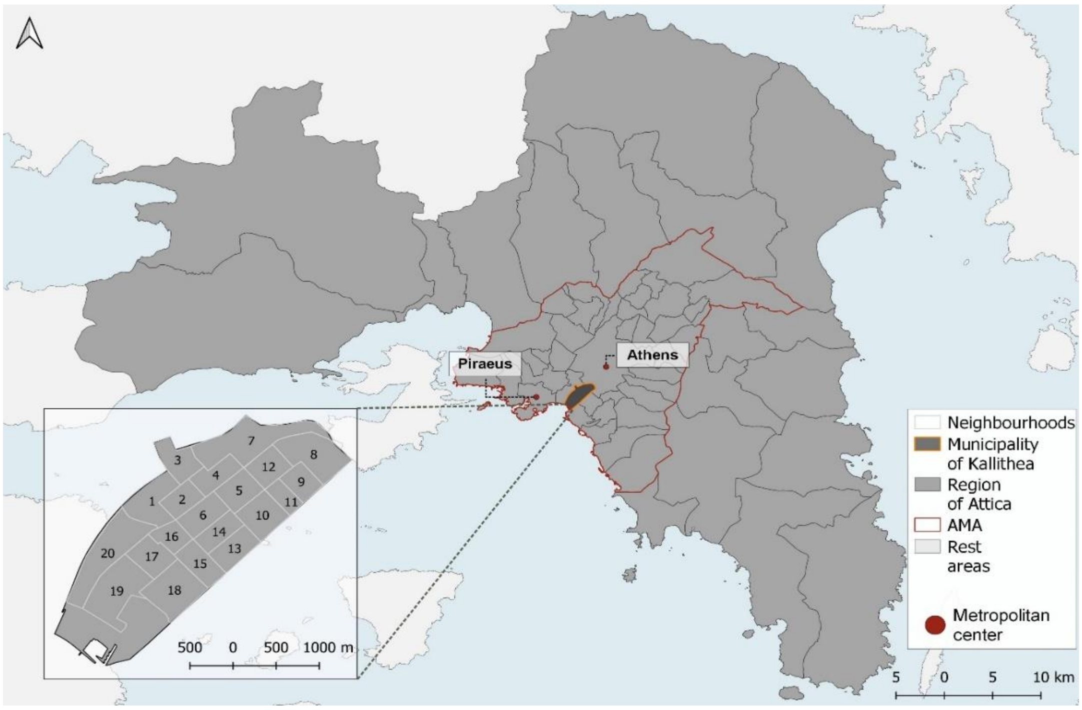


**Figure 3.** Study area of Kallithea within AMA.

## Results

### *Scenarios*

The conceptual design envisioning the future scenarios was translated into an actual street classification plan for each scenario, leading to interesting results. The spatial configuration of these four future conditions can be found in Figure 4. Furthermore, Table 1 summarizes the basic attributes for each scenario.

By looking at the relevant figure (Figure 4) and Table 1, the following should be underlined. First, it is demonstrated that Scenario 0 (baseline scenario) preserves the existing conditions and proposes six categories for organizing the street network. This scenario adopts a conventional approach, utilizing a one-dimensional matrix that gives priority to car movement. This fact signifies a low level of support for active modes. Lastly, although this scenario achieves fair readability, it neglects the urban perspective and does not formulate traffic calming zones.

In contrast, all the remaining scenarios outline visions embracing sustainable mobility. To be more precise, they adopt an alternative approach that utilizes a two-dimensional matrix (D1: street significance and D2: priority to modes). Therefore, one sees street categories that can accommodate a broad range of activities taking place in urban streets – they are not solely devoted to traffic. In addition, the scenarios propose nine categories, a value acceptable according to the literature in terms of creating readable street environments (Kosztolányi-Iván, et al., 2019). Within this framework, these backcasting scenarios introduce sustainable routes that include corridors of public transport and boulevards of active mobility. Additionally, they also propose shared space and pedestrian streets fully destined to vulnerable road users. Moreover, these three scenarios (1, 2 and 3) take the urban perspective into account, which is a street classification innovation towards the future. Finally, they also present fair readability through formulating traffic calming zones (in line with Mehaffy et al., 2010). The only major difference between them is that Scenarios 2 and 3 offer greater chances to vulnerable road users by setting traffic calming zones and sustainable routes throughout the study area.

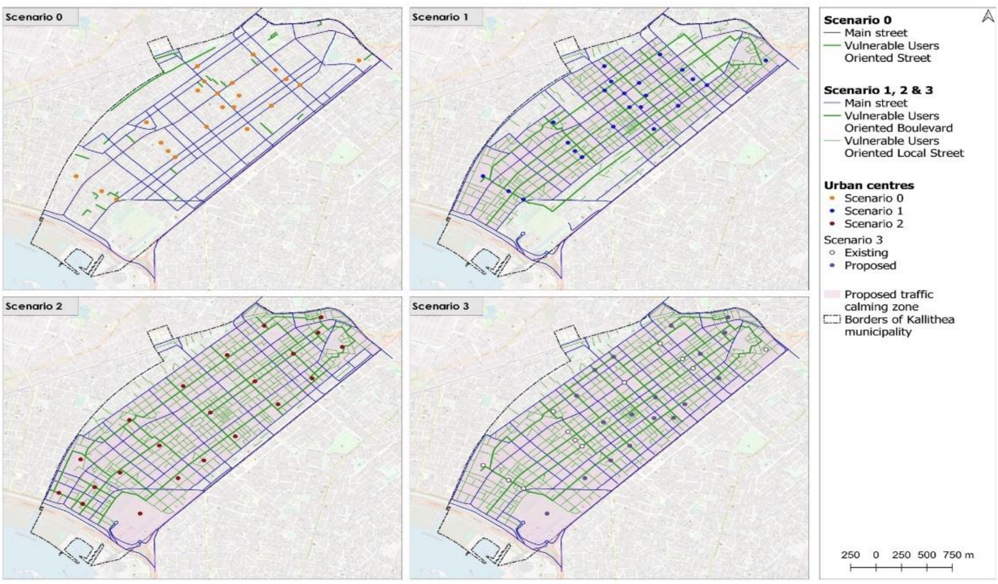


**Figure 4.** Proposed street classification scenarios. Main streets and vulnerable users-oriented streets

**Table 1.** Scenarios overview

| Basic characteristics | Scenario 0 | Scenario 1 | Scenario 2 | Scenario 3 |
|---|---|---|---|---|
| Categories | 1. Primary arterial<br>2. Secondary arterial<br>3. Collector street<br>4. Local roads<br>5. Traffic calming*<br>6. Pedestrian roads*<br>* Devoted mainly to vulnerable road users | Arterial streets<br>1. Strategic Car<br>2. Strategic PT<br>3. Intermunicipal PT Boulevards<br>4. Municipal PT*<br>5. Municipal Active modes*<br>6. Municipal Car Neighborhood streets<br>7. Local Active modes (Shared space)*<br>8. Local Pedestrian*<br>9. Local Car<br>* Devoted mainly to vulnerable road users | Arterial streets<br>1. Strategic Car<br>2. Strategic PT<br>3. Intermunicipal PT Boulevards<br>4. Municipal PT*<br>5. Municipal Active modes*<br>6. Municipal Car Neighborhood streets<br>7. Local Active modes (Shared space)*<br>8. Local Pedestrian*<br>9. Local Car<br>* Devoted mainly to vulnerable road users | Arterial streets<br>1. Strategic Car<br>2. Strategic PT<br>3. Intermunicipal PT Boulevards<br>4. Municipal PT*<br>5. Municipal Active modes*<br>6. Municipal Car Neighborhood streets<br>7. Local Active modes (Shared space)*<br>8. Local Pedestrian*<br>9. Local Car<br>‘*Devoted mainly to vulnerable road users |
| Approach | Conventional | Alternative | Alternative | Alternative |
| Dimensions | One-dimensional | Two-dimensional | Two-dimensional | Two-dimensional |
| Main priority to transport modes | Automobile | Active Modes | Active Modes | Active Modes |
| Sustainable routes | ✗ | ✓ | ✓ | ✓ |
| Support of active modes | ✪ | ✪✪ | ✪✪✪ | ✪✪✪ |
| Urban perspective | ✗ | ✓ | ✓ | ✓ |
| Readability | ✓ | ✓ | ✓ | ✓ |
| Traffic calming zones | ✗ | ✓ | ✓ | ✓ |

To provide a more detailed look regarding the length of active mobility streets per neighborhood in each scenario, the next figure (Figure 5) is presented.

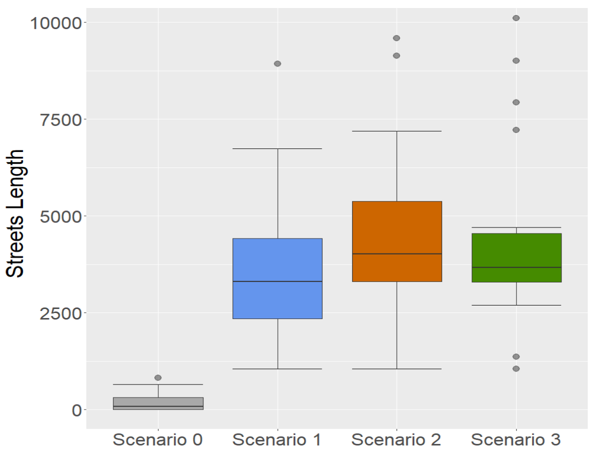


**Figure 5.** Boxplot displaying the streets length in meters prioritizing active mobility per neighborhood in each scenario.

Moreover, Scenario 2 displays the widest range of values, while Scenarios 1 and 3 reveal narrower ranges of values. Nevertheless, despite illustrating a concise range of values, Scenario 3 has the highest number of outliers. This means that some neighborhoods particularly benefit from the new street classification plan. However, will this outlier condition or the wide range of Scenario 2 function as a deterrent of equity? Insight into the impacts on equity can be found in the next sub-section. Lastly, it should be noted that the utilized GIS tools such as network analysis or mapping contributed to the efficient management of the available primary and secondary data. Also, detailed analysis employed in the GIS environment significantly assisted the transformation of scenarios into actual street categories.

When it comes to cross-sections and specific policy measures related to the new street categories (Scenarios 1-3), two detailed figures were developed (Figure 6 and Figure 7). Figure 6 shows eight groups with suitable measures and interventions for each street category. More specifically, the groups are the following: (conventional) car movement and type of junctions, speed limit (km/h), autonomous vehicle movement, on-street parking regulations, public transport, cycling infrastructure, pedestrian infrastructure (e.g., sidewalk width, streetscape features, potential coexistence) and land use (on the one hand car-oriented, such as big retail shops or industrial, and on the other hand small shops, parks, recreational uses, etc.). In Figure 7, all these policy measures were 'translated' into cross-sections (by using https://streetmix.net/), depicting how the street space should be allocated to different modes. These cross sections resemble some real-life streets of the study area. Nonetheless, these streets act as a conceptual example for a transport mode prioritization that can be transferred to roads with different road width values as well. This reflects some basic implications for cross-sectional equity; however, this concept was not examined in detail in the present research.

Observing these two figures (Figure 6 and 7), the following should be mentioned. It is clearly illustrated that street categories with strategic significance prioritize motorized movement, either in terms of car or public transport. Elevated junctions, big roundabouts, higher speeds, heavy public transport vehicles (even fixed-route, like trams) are proposed for these categories. Plus, they aspire to limit active movement to the bare minimum while presenting mainly car-oriented land uses. In a similar direction (but not exactly the same), intermunicipal streets will put greater emphasis on motorized than active movement. It should be underlined that autonomous vehicles appear as well. However, active movement is slightly enhanced compared to strategic routes. Car movement (and public transport) also prevails in car boulevards (C3) and local car roads (C6), where street modes are separated by sidewalks, driving (conventional or autonomous vehicles) and cycling lanes. Tellingly, active movement is supported in these categories, but not in full.

In contrast, four categories provide evident priority to active movement, thus putting users of active transport mode, i.e., pedestrians, cyclists, and people with disabilities, central in the street design. These categories (C4, C5, C7 and C8) deliver more considerable space to vulnerable street users (cycling lanes or tracks, ample sidewalks) while reducing speeds or even restricting motorized vehicles. Furthermore, they also make room for shared-space designs (C7) and they primarily invest in human-oriented land uses, where people can interact and communicate (like pedestrian malls, see Ismael et al., 2019). By establishing these new categories, cross-sectional equity will probably be improved, accommodating each user's needs, but more importantly these four categories are the main drivers for achieving spatial active transportation equity

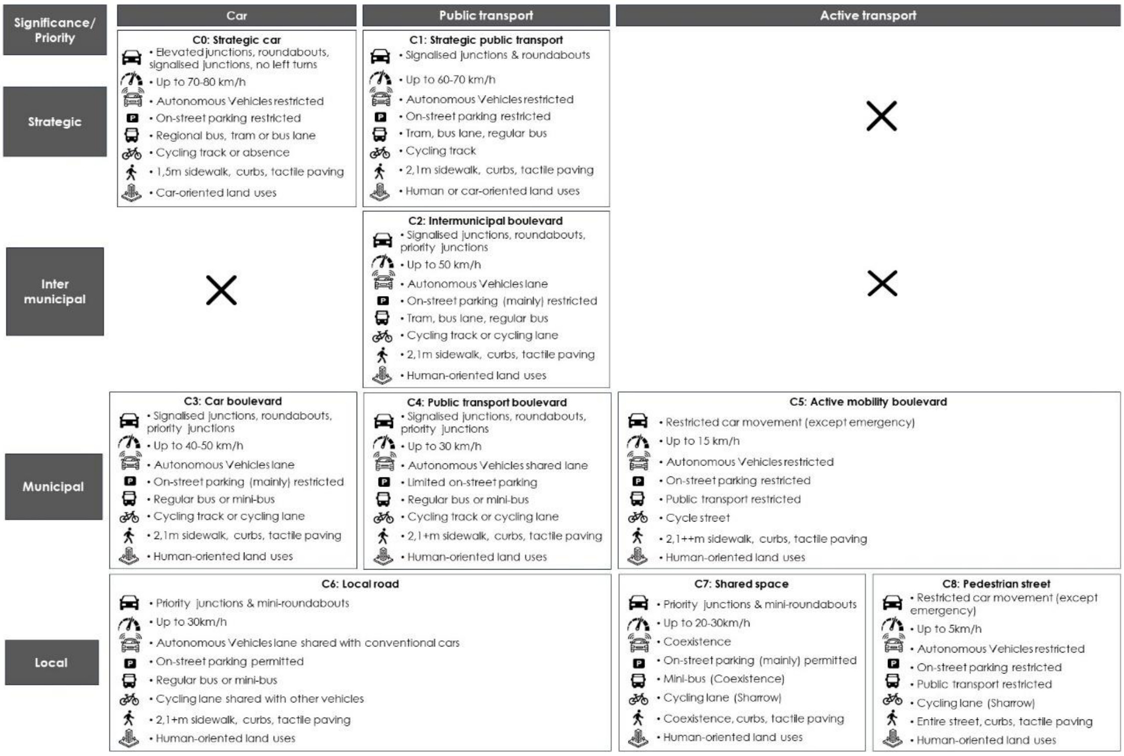


**Figure 6.** Policy measures and interventions per new street category.

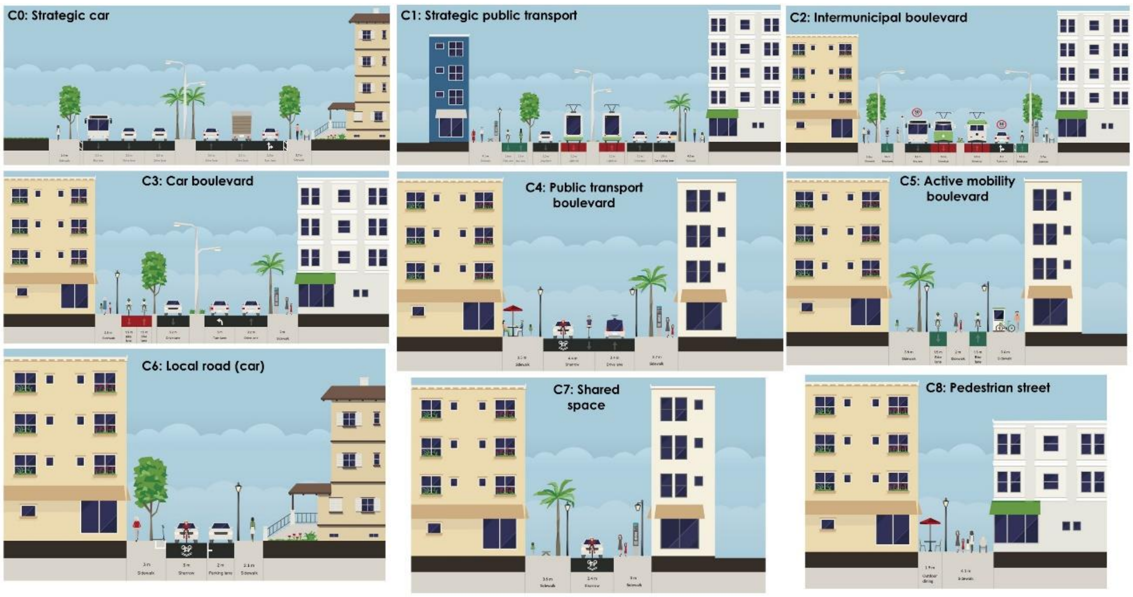


**Figure 7.** Example cross-sections per new street category

*Evaluation process*

<u>Egalitarian approach</u>

At this point, the Gini index and the respective Lorenz curves were calculated for each scenario. This helps to explore how each scenario contributes to achieve equitable distribution of infrastructure devoted to vulnerable road users. In detail, it is examined whether the length of vulnerable users-oriented streets is equally distributed among the population of neighborhoods (as determined by the General Land Use Plan). The next figure (Figure 8) illustrates the Lorenz curve as well as the Gini index per scenario. The curve outlining complete equity is presented in blue with the aim to be compared with the curves of the four scenarios.

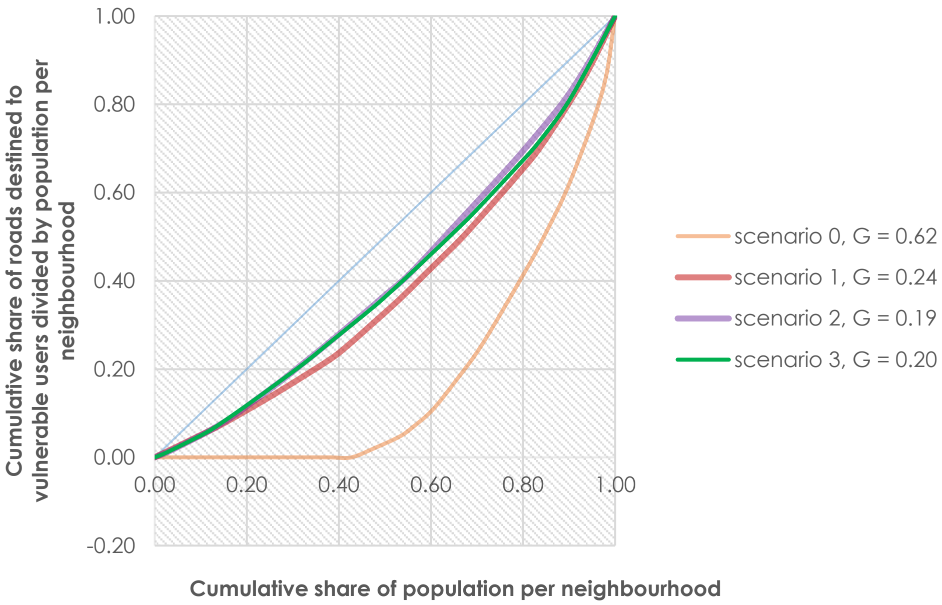


**Figure 8.** Lorenz curves per scenario.

As can be seen, Scenario 2 dominates marginally, since it has the lowest Gini index compared to the other scenarios. This specific Gini index value equals 0.19 while the index of Scenario 3 that follows is 0.20. Next in line, we encounter Scenario 1 with a Gini index of 0.2, and Scenario 0 with a much higher value, which equals 0.62. In general, it is worth underlining that the value of 0.19 is very close to 0. Hence, Scenario 2 can be considered not only as the best compared to the rest, but it has also the potential to provide an equitable distribution of vulnerable user infrastructure in the study area.

<u>Sufficientarian approach</u>

When it comes to sufficient conditions, this paper identified a sufficiency index for every neighborhood, meaning the ratio of streets prioritizing active modes to total street length, per scenario. Through this approach, ‘dark green spots’, ‘green spots’, or ‘light green spots’ perfectly or partially revealing sufficient conditions emerge, while ‘grey spots’, which cannot accommodate fair access to active modes, can also be distinguished. More specifically, it is crystal clear that the existing conditions (scenario 0) are ‘hostile’ for pedestrians, cyclists, and people with disabilities. In contrast, new scenarios like 2 and 3, could be deemed sufficient, paving the way for a fair amount of active movement in the area (especially Scenario 2 achieves a higher number of perfectly efficient neighborhoods, namely seven neighborhoods). To achieve this appreciable sufficiency policy, recommendations adjusted to each scenario should be realized. Notwithstanding, further notice should be given to the grey spots as well as the light green spots (at a later stage) and bearing that in mind even the most equitable scenario (Scenario 2) should be (slightly) reconsidered. Notably, the threshold is proper for the Greek context and the Mediterranean in general; however, current reality is far removed from this situation, signifying the urgency for customized policy measures and interventions. All of the above is presented in the following figure (Figure 9), which is an overview map that illustrates the four scenarios accompanied by the dark green, green, light green and grey spots.


**Figure 9.** Sufficient conditions analysis. Dark green, green, light green and grey spots.

## Discussion

This research shed light on how different street classification scenarios in a municipality within a metropolitan area will affect the distribution of infrastructure devoted to vulnerable road users. Is this distribution equitable or not? Nowadays, equity concerns should be the cornerstone of evaluating projects and scenarios (Pereira and Karner, 2021). CBA or MCA procedures that do not consider the distribution of transport impacts fail to comprehend today's complex urban transport systems (Shi and Zhou, 2012). To this end, this study employed spatial planning and evaluation via the Gini index and Lorenz curves as well as through a simple sufficiency index (in line with Guzman et al., 2017; Niehaus et al., 2016; Martens et al., 2022). This method led to simple but at the same time insightful results.

In summary, equity conditions seem to improve considerably if alternative street classification schemes are realized. To be more precise, the Lorenz curves show clearly that scenarios adopting radical solutions like rethinking urban centers, formulating traffic calming zones, and street categories intended for vulnerable road users may offer fair access to the population of the area. This result was confirmed by the sufficiency index as well, where Scenarios 2 and 3 achieve a greater number of 'sufficient' and 'perfectly sufficient' areas compared to the rest. Besides, scenarios like Scenario 2 or Scenario 3 (interestingly, Scenario 2 results in a lower value of the Gini index, a higher median of the sufficiency index, and a greater number of perfectly efficient neighborhoods), are not only favorable for active mode users or disabled people, but also address car user needs on the basis that they can now shift to active modes easily. Similar findings have been demonstrated in similar papers (unfortunately relevant papers incorporating scenarios are very limited). For instance, Guzman and Oviedo (2018) underlined that scenarios appraising sustainable mobility improved equity in Bogotá, Colombia. In the same line, Pereira (2019) argued that expanding public transport services in Rio de Janeiro, Brasil, may lead to better equity conditions. Lamu et al., (2021) found that cycling expansion scenarios in Oslo were in favor of equitable active transportation equity conditions.

Apparently, these two scenarios orchestrate categories that highlight the multispectral identity of urban streets, going beyond the dominant car-oriented paradigm (in accordance with Tumlin, 2012). Therefore, the social impacts of these two prevailing scenarios would be beneficial both for people experiencing (potential) social exclusion and for people still preferring their private car today. Tellingly, new street classification rationales pave the way for gradually 'liberating' streets from cars (Tsigdinos and Vlastos, 2021) and fostering social interaction and a community feeling instead of individualism in public space, even in challenging areas like Kallithea, Greece. These two scenarios managed to 'eradicate' grey spots of non-sufficient conditions. This is a very important ex-ante achievement. However, although being drivers for enhancing fairness in the transport system, some light green spots still exist. It is natural that even radical scenarios need time and community acceptance to transform an area entirely. Nevertheless, the sufficientarian approach calls for the reconsideration of the scenarios through the lens of an even more holistic strategy with the ultimate aim of cultivating perfectly sufficient conditions in all neighborhoods. Relevant papers underline the possibility of not achieving 'ideal' conditions. Surprisingly, certain studies indicate the risk of worsening existing conditions related to equity or sufficiency, even when progressive measures are adopted (Pritchard et al., 2019; Mora et al., 2021). This is due to the lack of establishing an integrated planning approach that truly focuses on vulnerable users and acknowledges their real needs.

Bearing the present findings and current literature in mind it becomes evident that future schemes outlining policy measures and interventions should be looking for an inclusive mobility context, promoting both new street categories and redefining urban centralities (see also Mehaffy, 2010). Simply put, the focus should be on integrated urban and transport planning approaches (in line with Capasso Da Silva et al., 2020). Coupled with new narratives at a constitutional and formal planning level, communities should be involved actively in street classification planning, thus enabling the transition to inclusive and sustainable mobility futures (Gil et al., 2011). But most importantly, there should always be room for reconsidering scenarios to identify solutions that really improve equity in terms of distribution and sufficiency of transport modes.

Regarding the impacts, the following should be stressed. The impacts are mainly of local value, as they address the distribution of active mode infrastructure in the neighborhoods of Kallithea, a car-oriented municipality within a car-oriented metropolitan area. Exploring equity issues locally gives the opportunity to document problems and risks in detail (Zuo et al., 2020). This would be a strong asset towards improving conditions for active mobility and particularly helpful for setting a comprehensive policy framework for the future (Berg and Newmark, 2021). Hence, knowing about these impacts would be of great value to policy makers, planners, consultants and local administrators who can consider these outcomes when developing new policy measures and interventions. In other words, these expert groups could use the presented method to create multiple future pathways (accompanied by police measures and interventions) and also evaluate them afterwards. This will help them understand the dynamics of their city and also expand the possibilities of transformation in the future. After all, depending on only one future scenario ignores the uncertainty and complexity of urban/suburban areas (Lyons et al., 2016). In contrast, building more pathways will address future issues and challenges in a holistic manner. Policymakers need simple tools that guide them while not restricting them. Hence, this method is a supportive tool towards this direction. On the one hand, it provides certain guidelines and assistance for the street classification planning (specific features, cross-sections, evaluation measures), whereas on the other hand, it cultivates creativity (opportunity to build various scenarios). In this context, they could give emphasis on specific measures and interventions that will enhance equity for pedestrians, cyclists, and micromobility users, stimulating a cohesive social policy, particularly in the identified grey and light green spots. Tellingly, this social policy framework could be a tool for tackling social exclusion as well (conforming to Lucas, 2019). However, active transportation equity should not be limited to the local scale; this study could function as a basis for extending the analysis to the macroscale as well.

Looking closely at the method employed, the following should be stressed. First and foremost, this method lies at the heart of the integrated urban and transport planning approach. Therefore, a combinatorial rationale is embraced. This rationale utilizes different tools and techniques from a holistic perspective. More specifically, spatial analysis is coupled with scenario planning and welfare economics with the aim to explore current conditions (both urban and transport data), create future pathways (scenarios dealing with main road network and urban centralities differently) as well as to assess these pathways through the lens of active transportation equity. Cross-sectional distribution is also addressed. This combinatorial approach comprises a novel method, enabling comprehensiveness and efficiency. Hence, it is regarded as highly suitable for addressing the objectives of the present research. Moreover, the steps are rather simple and clear, thus providing reproducibility opportunities to other contexts and urban environments.

When it comes to the contribution of this study, it should be acknowledged that it is one of the first to date that examined how different street classification scenarios will affect vulnerable users' access to streets adjusted to their needs. Nevertheless, it is a small step towards the understanding of how active transportation impacts are distributed. This research focused on an equitable distribution across neighborhoods, with the neighbourhoods setting the overall population as the centerpiece. In other words, it was a quest for horizontal equity, overlooking differences between social groups. This surely limited the richness of the results. For this reason, detailed works in the future may deepen their analysis by investigating how these different scenarios affect specific social groups, such as the elderly, immigrants, low-income households, etc. (see also the work of Arranz et al., 2022 on the elderly). Are these groups treated fairly or do they experience social exclusion issues?

Concerning other limitations, it should be mentioned that the method followed does not involve public nor expert participation in the planning or evaluation stage. This definitely narrowed some more potential insights regarding the scenarios and their impacts. Hence, we recommend new research to examine public engagement. Moreover, future papers could employ advanced geospatial methods for planning street classification (i.e., deep learning algorithms on network analysis) and utilize simulation tools (e.g., agent-based simulation) for assessing how equitable active mobility-oriented streets are. For instance, they could examine how each street functions and identify its role and impact on the modal split and travel behavior in an accurate manner. Additionally, this paper did not focus on cross-sectional equity and specifically how much street space is dedicated to each mode. This fact signifies critical equity issues about urban streets. Thereupon, future research could concentrate on this aspect. Another limitation that may be overcome in future studies is that the policy recommendations are not so flexible. To this end, scenarios could be built not only for the spatial and organizational aspect of street classification but also for policy measures and interventions (for instance speed, lanes, type of cycling, or walking infrastructure, etc.).

What is more, new research attempts or projects could explore how planning schemes (formal or informal) may improve equity conditions through the lens of sufficientarian theory (Martens, 2016), going beyond the preliminary nature of this paper. Therefore, these works may employ a set of policy measures and interventions based on the present findings. Besides, these findings could be transferred to areas with the same characteristics as the study area of Kallithea in Athens (e.g., central municipalities in metropolitan areas). Consequently, this paper functions as a scene setting work, endeavoring to inspire research attempts and opening a dialogue about street classification and equity concerns.

## Conclusions

This paper employed a mixed-method approach, using scenario planning and spatial analysis to examine what are the impacts of rethinking street classification on active transportation equity. Developing future scenarios is helpful for identifying impacts and gaining key insights with the aim of setting policy recommendations. Moreover, spatial analysis facilitates the measurement of the proper indices to illustrate how equitable and sufficient each scenario will be. Therefore, scenario planning and spatial analysis could be of great use when looking at the impacts on a specific issue and especially on issues related to infrastructure and equity.

Car-oriented policies are a barrier to enhancing equity related to walking and cycling infrastructure. Thereupon, the conventional approach of prioritizing automobiles should be replaced by an alternative one favoring multimodality and especially vulnerable users. New classification schemes like the one proposed in this paper could lead to new road space allocation by employing policy recommendations (shared space, restriction of cars in certain roads, active mobility boulevards, etc.) and by building the appropriate infrastructure for vulnerable users such as sidewalks, ramps, streetscape features, etc. Plus, active transportation equity plays a great role. The understanding of how equitable and sufficient the urban road conditions are, especially for the people living, interacting, and socializing in a city, is a critical factor for addressing wider societal challenges. For this reason, the scientific debate and practice should continue to examine how urban mobility scenarios affect equity with the aim to create inclusive cities and accessible urban road environments.

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