Sustainable Mobility Guarantee under the 15-Minute City Concept: A Framework for Urban Travel Equity and Spatial Optimization

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***Abstract*—In the context of worldwide climate change and the spread of cities, the idea of the "15-Minute City" has become very popular among scholars and policymakers as an important planning paradigm to support the localization of daily essential services and low carbon travel. Nevertheless, current studies mostly deal with high-density accessibility analysis on urban cores, frequently failing to consider the travel requirements of marginal regions and disadvantaged populations. Such an omission leads to not translating the spatial notion of proximity into the social notion of travel equity. Old-fashioned transportation planning does not have a standardized guarantee system that would combine environmental restrictions with social inclusion. Based on the idea of the Sustainable Mobility Guarantee (SMG), this paper suggests a spatial optimization model that incorporates accessibility modeling, spatial equity measures, and multi-modal transport synergy. Through the creation of a multi-modal accessibility model that is quantifiable in terms of spatial units, which considers walking, cycling, public transit, and inexpensive micro-circulation feeder assumptions, we quantify the gap in travel equity between various spatial units. This paper uses the Two-Step Floating Catchment Area (2SFCA) method and the Gini Index to measure the spatial equity of existing service facilities based on reproducible urban data sets, such as open POI records, OpenStreetMap road networks, and publicly available transit stop and schedule information, in a typical peripheral built-up area in Shanghai as a demonstration scenario. After that, three guarantee scenarios with varying degrees of low-cost networks and service modifications are simulated with transparent and repeatable parameter assumptions. It is found that the mere reduction in physical distance will not lead to genuine travel equity: currently, the Gini index in peripheral areas is at 0.42, which means considerable spatial deprivation. With the improved guarantee scenario under the simulated multi-modal SMG mechanism, the total regional accessibility Gini index decreases to 0.28, which implies that the service gap between core and peripheral groups narrows significantly within the given modeling assumption. The present work reinterprets the idea of the 15-Minute City as a spatial proximity concept and turns it into a reproducible and low-cost transportation guarantee evaluation tool, offering theoretical background and quantitative decision-making assistance to urban planners to optimize their resource use and improve the travel rights of vulnerable populations when budgeting.**

Keywords*—15-Minute City, Sustainable Mobility Guarantee, Travel Equity, Spatial Optimization, Accessibility Modeling

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I. Introduction

Along with the rapid increase of global urbanization, automobile-oriented urban spatial structures have not just caused heavy traffic and carbon emissions, but also increased spatial disparities between various social classes in access to urban public facilities [1]. Over the last few years, the idea of the so-called 15-Minute City, which seeks to redesign urban space structures to minimize long distances traveled, has become popular around the world both in theory and practice as an important paradigm that is relevant to climate change and urban resilience [2]. The concept suggests that people ought to be able to access their most fundamental needs in life, i.e., employment, schooling, medical care, shopping, and leisure, within a 15-minute walking or bicycle distance. Its primary value is the integration of urban time costs as central to spatial planning, which leads to a paradigm shift on urban growth as car-centric to being people-centric.

Nevertheless, despite the fact that the concept of the «15-Minute City» theoretically portrays the very sustainable picture of the urban life, its application in practice is subject to serious difficulties. First of all, the accomplishment of the so-called 15-minute goal in urban peripheries, suburbs, and low-density developed zones is quite complicated because it requires a small number of facilities allocation and poor quality of public transport services, which may cause new types of spatial deprivation [3]. Second, the current accessibility planning does not consider the differences among the different population groups, which include the elderly, low-income households, and people with disabilities, in terms of access to vehicles, mobility, and time constraints [4]. Such simplified quest of proximity, without the aid of organized transportation systems, is hard to genuinely embody as travel equity.

In order to deal with this drawback, academia has started to examine the idea of the so-called Mobility Guarantees. Newer findings show that it is not enough that the transportation policies should satisfy the minimum level of service standards they must also establish some binding goals in order to prioritize the non-motorized and public transport as the ultimate goal, i.e., the so-called Sustainable Mobility Guarantee (SMG) [5]. At the same time, new investigations on policies of X-minute-cities also reveal that accessibility enhancement should be integrated with spatial optimization to ensure efficiency and equity in various urban areas [6]. In the context of distributive justice, transport equity should not merely consider the level of average accessibility, but also consider whether accessibility benefits are distributed fairly among various social groups [7]. Empirical research on access to work and study has demonstrated that transport inequity is commonly caused by the mismatch between the distribution of opportunities and the real transport situation [8]. The current research on environmental justice also indicates that the spatial network analysis and data-based methods can assist in identifying unequal exposure and service conditions at the scale of urban micro-areas [9].

The main research question that will be explored in this study is: How can the introduction of a Sustainable Mobility Guarantee mechanism resolve the imbalance in spatial resources during the formulation of the 15-Minute City and bring about the synergistic optimization of the urban travel equity and spatial structure? To respond to this, the aim of this study is to develop a cost-effective and repeatable evaluation system incorporating spatial accessibility and social equity, and investigate the application of the synergy of multi-modal transportation in minimizing spatial inequalities by means of scenario-based simulation. This study is restricted to commuting and non-commuting travel in daily essential living spheres, with emphasis on the joint effectiveness of walking, cycling and public transport, but does not consider the use of private automobiles. The paper structure is presented as follows: Section 2 - Literature Review; Section 3 - Related Works and Positioning of the Study; Section 4 - Research Methodology and Model Framework; Section 5 - Introduction of Publicly Accessible Data Sources and Processing Procedures; Section 6 - Scenarios Simulations and Analysis of Results; Section 7 - Engaging in a Detailed Discussion; and at last, conclusions and policy implications are made.

II. Literature Review

A. From the "15-Minute City" to "Spatio-Temporal Equity"

The essence of the so-called "15-Minute City" is the principle of "chrono-urbanism," which will restructure the urban time and space to minimize the cost of spatio-temporal access to essential services by citizens. According to empirical research on 15-minute walkable neighborhoods, facility coverage and walkability are two useful indicators of daily accessibility, although these measures might also be used to uncover major social disparities among various communities [10]. It has also been linked to the net-zero urban transition since compact service delivery and minimized long-range transportation may help low-carbon urbanization and increase resilience in the community [11].

Nevertheless, more and more scholars have noted that facility proximity is not synonymous with equality of opportunity. Uneven housing markets, selective investments in infrastructure, and disparities in environmental quality can make highly accessible and climate-safe places socially inaccessible, which leads to the phenomenon of climate-gentrification [12]. Thus, it is necessary to switch to the concept of "spatio-temporal equity" instead of the purely spatial proximity, including such factors as individual mobility and the quality of transportation services into consideration. The shift is important because transport justice offers a significant normative framework of analyzing the just access as a social right and not just as a technical planning result [13]. Furthermore, the concept of fair accessibility should be viewed in terms of both civil-rights-based planning principles and quantifiable accessibility standards [14].

B. Methods for Measuring Transport Equity and Accessibility

The evaluation of transport equity is important to assess the success of urban planning. The conventional transportation planning will frequently consider the road capacity and the mean travel time as fundamental measures; such a car-centric attitude hides the negative aspects of travel experienced by those who have no access to cars. Accessibility-focused equity assessment has been the leading research paradigm over the last few years. The methods of spatial accessibility in GIS offer a practical framework to determine if the necessary services are available at an affordable distance by taking into account the interdependence between the facility supply, population demand and distance travelled [15].

In low density or rural areas, mobility innovation research has highlighted the need to combine public transport, shared mobility and flexible services in order not to exclude those living outside the dense urban cores [16]. Sustainable urban mobility planning that focuses on equity indicates that climate objectives and social inclusion objectives are supposed to be handled together instead of being dealt with separately as policy objectives [17]. In the context of urban design, street environments that are people-centric also affect the possibility of walking and cycling becoming a viable mode of daily travel as a plan rather than as an abstract assumption [18].

Regarding measurement tools, research conducted on the concept of the Global South has shown that modeling spatial accessibility and social equity in cities may prove useful when assessing whether proximity-based policies can also be implemented outside high-density cores areas [19]. The Floating Catchment Area family of methods, such as advanced multi-step approaches, is useful since it considers both the supply of facilities and population demand together with the travel impedance [20]. The fact that improvements to the Two-Step Floating Catchment Area method demonstrate even further the necessity to adapt distance-decay functions and catchment definitions to various settlement contexts, particularly where facilities are scarce or travel distances are great [21] is worth noting.

C. Theoretical Evolution of the Sustainable Mobility Guarantee (SMG)

The idea of Mobility Guarantees has its roots in the equalization of public service policies, which originally intended to offer even basic public transit links to remote and unattended regions. Within the wider framework of urban transformation, resilience, inclusion and access to public services are now anticipated to become part of the spatial planning of future cities and mobility governance [22]. To be more precise, studies on transport poverty demonstrate that the absence of affordable, dependable, and accessible transportation may have negative effects on society and thus the minimum provision of mobility becomes an issue of social equity not simply a case of convenience [23]. On an even more theoretical basis, the creation of urban space cannot be extricated of power dynamics and social entitlements, implying that accessibility gaps need to be viewed as spatially generated inequalities and not just purely technical issues of networks [24].

According to this theoretical development, SMG may be viewed as not just a social-economic safety net but also as a strategic instrument to achieve climate neutrality, reduce the use of cars, and enhance the spatial justice. SMG is not limited to the traditional mode of public transport (PT) but also incorporates active transport (AT), i.e., walking and cycling, and demand-responsive transport (DRT) into an organized system of mobility rights. Nevertheless, the existing studies on SMG are mostly at the macro-policy analysis stage, and there are not many works that combine SMG with the micro-level planning of the living circles of the so-called 15-minute city.

III. Related Work

The intersection between the concept of the 15-Minute City and transport equity shows a current research tendency towards moving away from macro-concepts and towards micro-measurement, and away from assessing accessibility based on only a single mode of transport and towards multi-modal synergy. Table I is a summary and comparison of some representative works. A survey of the aforementioned works indicates that although measurement methods of the 15-minute city are reaching maturity, there is a need to explore further ways of closing space gaps using practical, inexpensive, and repeatable transportation policy models and facility adjustment strategies like SMG. The novelty of the present work can be described by the fact that it creates a closed-loop model of the Facility DistributionMobility GuaranteeEquity Evaluation which not only uncovers the existing inequities but also measures the possible spatial optimization effectiveness of various transportation guarantee plans based on clear and repeatable scenario simulation.

TABLE I. Comparative Analysis of Existing Related Research

Reference	Core Methodology	Research Context	Main Limitations
Moreno et al. (2021) [2]	Conceptual framework construction	Paris and global core areas	Lacks quantitative measurement and spatial heterogeneity analysis
Poorthuis & Zook (2023) [3]	Accessibility analysis	Entire Netherlands	Does not propose optimization solutions
Shibayama & Laa (2024) [5]	Institutional classification and policy framework	National level (Austria)	Not scaled down to urban micro-level
Jiang & Ma (2025) [9]	Machine learning + spatial networks	Urban micro-blocks	Focuses on environmental exposure rather than transport supply
Wang et al. (2026) [6]	Spatial optimization models	Transport networks	Insufficient consideration of systematic guarantees for non-motorized transport
Guzman et al. (2017) [8]	Gini Index + Accessibility	Bogotá	Only diagnoses inequity; lacks intervention simulation

IV. Methodology

A. Research Framework and Strategy

The paper has a replicable technical approach of "Status Assessment-Scenario Construction-Effect Simulation" due to the use of publically available information and clear assumptions of the parameters, as shown in Figure 1. Initially, using open-source spatial data and transport data available to the general public, a multi-modal transportation network is created to assess the baseline accessibility of important services and spatial equity in the study region.]Next, the idea of SMG is converted into practical spatial intervention measures, and it is determined that there are three low-cost transportation network adjustment and service optimization scenarios. Lastly, through the repeated execution of the same accessibility models and equity indicators the potential optimization effects are quantitatively compared to ensure that the outcomes can be reproduced in similar conditions.

The Two-Step Floating Catchment Area (2SFCA) approach applied in this research has been improved to measure the potential of spatial units to access essential urban services with the help of publicly available and reproducible spatial data [15]. The conventional version of the 2SFCA has largely assumed a single mode of transportation, but this paper builds upon this to incorporate a multi-modal composite model of walking, cycling, public transport, and low cost feeder modes that can be made use of by building on currently available or simple to modify local transport systems.

Stage 1: Determine the Supply-to-Demand Ratio of Service Facilities. All the demand points (the residential area) k in the 15-minute isochrone (threshold time t 0 = 15 mins.) are searched by every service facility j. The supply-to-demand ratio R j is defined as:

$$R_j = \frac{S_j}{\sum_{k \in d_{kj} \le t_0} D_k \cdot W(d_{kj})} \quad (1)$$

Here S_j is the service capacity of facility j; D_k is the population of the demand point k; d_{kj} is the minimum travel time between k and j based on the multi-modal network; and d_{kj} is the Gaussian distance decay function.

Calculate the Composite Accessibility of Spatial Units. To each demand point i, search all facilities j in its 15-minute isochrone to calculate a composite accessibility A_i by weighting and summing the supply-to-demand ratio of all the searched facilities:

$$A_i = \sum_{j \in d_{ij} \le t_0} R_j \cdot W(d_{ij}) \quad (2)$$

B. Spatial Equity Evaluation Indicator

In order to measure the distributional differences of accessibility between spatial units and populations, the Population-Weighted Gini Index [8] is proposed in this study. The Gini index is a number between 0 and 1 with values closest to 0 being more equal distribution of resources. The equation is:

$$G = \frac{1}{2\mu N^2} \sum_{i=1}^{N} \sum_{k=1}^{N} P_i P_k |A_i - A_k| \quad (3)$$

With N being the whole quantity of spatial units; P_i and P_k are population shares of units i and k; A_i and A_k are the respective accessibility indicators; and u is the population-weighted mean accessibility of the whole region. According to the international practice, the Gini index of 0.30 is taken as the boundary of the relative equity [22].

C. *Sustainable Mobility Guarantee (SMG) Scenario Setting*

Considering the SMG model of Shibayama and Laa [5], this paper sharpens the concept of mobility guarantees into three practical spatial interventions which are: (1) Enhancement of Active Transport Network; (2) Enhancement of Public Transit Service; and (3) Introduction of a feeder system of micro-circulation based upon the assumption that there is an existing community shuttle, flexible-route, or demand-responsive service.

Three optimization scenarios are established:

- Baseline Scenario (Status Quo): Maintains the current transportation network and service levels.
- Moderate SMG Scenario: Only applies low-cost active transport network upgrades including repairing missing links, cross-continuity, as well as slow traffic connections and assumes that there will be a rise in network connectivity of around 15%.

The High SMG Scenario: It is based on the improvement of active transport facilities through the enhancement of accessibility to existing public transit terminals and the imitation of low-cost micro-circulation feeders, and the average waiting times and feeder distances are optimized under clear-cut assumptions and feeder access distances reduced to less than 300 meters in non-centralized areas.

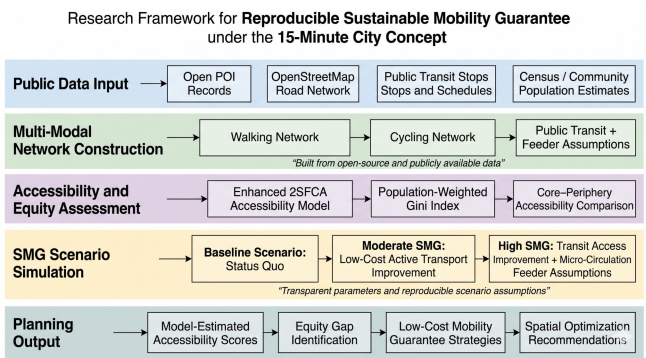

Fig. 1. Research Framework for Reproducible Sustainable Mobility Guarantee under the 15-Minute City Concept

V. DATA

A. *Study Area and Data Sources*

The research chooses an average peripheral built-up region in Shanghai as an example that would be used to test the reproducible evaluation structure. The area of around 45 square kilometers contains old industrial zones, new residential areas, and urban villages (Chengzhongcun), with a clear population distribution heterogeneity in the form of a core-periphery.

The data required for the study include:

1) Population and Spatial Unit Information: Resident population distribution based on publicly available census statistics, community-level population records and residential land use information at grid-level (200m x 200m) of the total of 1,122 valid spatial units.

2) Service Facility Data (POI): Data on Points of Interest were obtained by filtering out five major categories of "15-Minute City" services (Daily Commerce, Education, Healthcare, Recreation, and Transit Hubs) based on the publicly available map-based POI sources as of January 2025. In this process, duplicates and incomplete records were eliminated and 3,378 valid facilities have been maintained.

Transportation Network Data: The underlying road network was taken out of OpenStreetMap (OSM) and augmented by special walking and cycling tracks that were determined using open map layers, satellite imagery analysis, and freely available street network data. The data on public transit stops, routes and schedules were provided using the data available in the open transport data sources and the open data platform of Shanghai Municipal Transportation Commission, when applicable.

B. *Descriptive Statistics*

According to Table II, the standard deviation of the number of accessible facilities within a 15-minute walk is high (12.6), which implies spatial inequity in allocation of service resources as measured by the public-data-based framework. Also, the time to the closest bus stop in the peripheral units is 28 minutes in some cases, much longer than the anticipated time of the concept of the "15-Minute City, " and this underscores the urgent need to implement mechanisms that would guarantee mobility.

TABLE II. DESCRIPTIVE STATISTICS OF KEY VARIABLES IN THE PUBLIC-DATA-BASED STUDY AREA

Variable Name	N	Mean	Std. Dev	Min	Max
Grid Population (persons)	1,122	452.3	215.8	12	1,840
Number of Facilities within 15-min Walk	1,122	18.4	12.6	0	65
Walking Time to Nearest Bus Stop (min)	1,122	8.2	4.5	1.5	28
Facility Service Capacity Weight Index	3,378	1.54	0.82	0.5	5

VI. RESULTS

A. *Baseline Spatial Accessibility and Equity Assessment*

Under the baseline scenario, accessibility analysis implies obvious spatial deprivation of the study area with the given data and modeling assumptions. The model calculations indicate that the average composite accessibility score (A_i) in the demonstration setting is 4.82 in the core build-up area, and it is 1.35 in the urban periphery and urban villages. More than 35.2 percent of the peripheral population do not have access to at least three of the five fundamental services within a 15-minute walk or cycle.

The population-weighted composite accessibility Gini index of the whole region in the baseline scenario is 0.42, which is very high, and this reflects the fact that the distribution of service resources is extremely unequal. It suggests that the current approach to the transportation network might not suffice in realizing the equalization objectives of the so-called "15-Minute City."

B. Spatial Optimization Efficacy under SMG Scenarios

After simulations of various Sustainable Mobility Guarantee (SMG) approaches, regional accessibility and equity indicators have significant changes based on the given conditions (Table III and Figure 2).

The simulation findings show that the Moderate SMG Scenario, which maximizes only the current mode of transport network, adds an extra 20.0 percent to the overall average accessibility, where the Gini index goes down to 0.35. The main cause of this enhancement is based on the idea that walking dead-end streets and missing slow-traffic connections in remote regions are eliminated.

The High SMG Scenario with combined assumptions of optimizing active transport and improving access to transit and micro-circulation feeders demonstrates the highest modeled improvement. The overall average accessibility was improved by 64.2 percent in the simulation. Of more significance, the average accessibility in peripheral regions rose by 181.5 percent (1.35 to 3.80) and the core-periphery gap ratio reduced by 3.57:1 to 1.54:1. As shown in Figure 3, the Gini coefficient dropped to 0.28, which is below the relative equity level of 0.30. It is implied that the multi-modal transportation guarantee strategies, when applied in the form of viable network and service changes, may be able to offset the built-in shortcomings of spatial facility arrangements.

C. Service-Type Specific Responses

The additional breakdown of the accessibility improvements within the five service categories shows different reactions to the mobility guarantee strategies (Figure 4). The greatest modeled improvement in accessibility is shown by healthcare facilities, where there is a 203 percentage point increase in accessibility periphery area under High SMG conditions because they have a relatively concentrated spatial distribution that can be easily connected by micro-circulation feeder assumptions. On the other hand, the daily commerce had lower increments (124%) because the convenience stores were more spread out, and thus their availability was more reliant on the actual existence of a facility as opposed to network optimization.

D. Sensitivity Analysis

The sensitivity tests were performed on the distance decay parameter and threshold time to confirm the strength of the findings (Figure 5). Changing the decay parameter by β between 40 and 80 made the Gini index at the High SMG situation vary slightly between [0.26, 0.30]. The trends are largely unchanged with the main conclusions, which is that the spatial optimization model developed in this paper has a reasonable level of robustness across the given range of parameters that were tested.

TABLE III. COMPARISON OF MODEL-ESTIMATED ACCESSIBILITY AND EQUITY INDICATORS ACROSS SCENARIOS

Indicator	Baseline	Moderate SMG	High SMG
Overall Average Accessibility Score	2.85	3.42 (+20.0%)	4.68 (+64.2%)
Core Area Mean	4.82	5.10 (+5.8%)	5.85 (+21.4%)
Peripheral Area Mean	1.35	2.15 (+59.3%)	3.80 (+181.5%)
Core-Periphery Disparity Ratio	3.57 : 1	2.37 : 1	1.54 : 1
Gini Index	0.42	0.35	0.28

a. Note: Values are model-estimated results under transparent scenario assumptions rather than outcomes from costly field experiments or real-world intervention deployment.

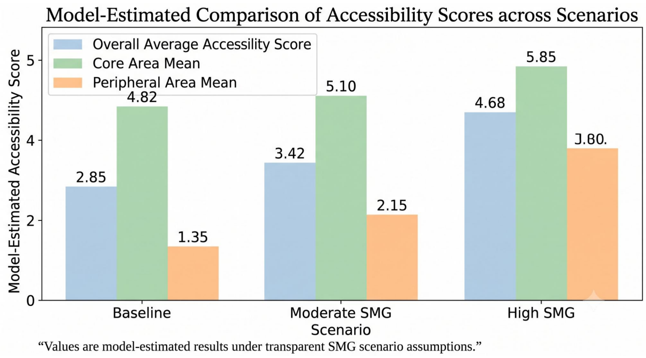

Fig. 2. Model-Estimated Comparison of Accessibility Scores across Scenarios

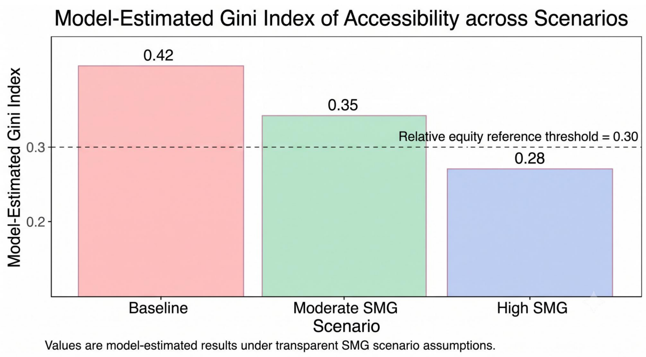

Fig. 3. Model-Estimated Gini Index of Accessibility across Scenarios

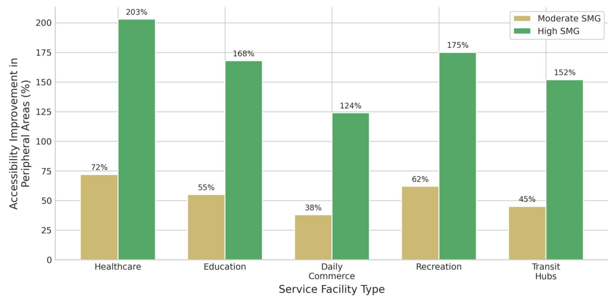

Fig. 4. Service-Type Specific Accessibility Improvement in Peripheral Areas

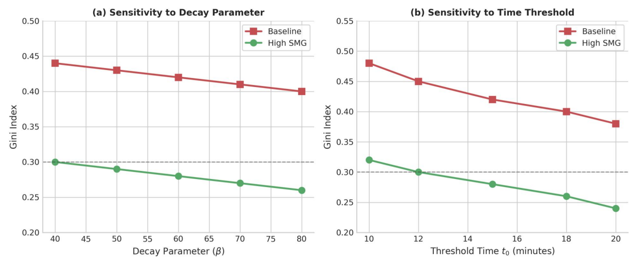

Fig. 5. Sensitivity Analysis of Key Model Parameters under Reproducible Assumptions

VII. Discussion

A. Horizontal Comparison and Theoretical Contributions

The results of this research support the statement that the concept of proximity is not equivalent to accessibility or even equity, which can be considered a very close fit to the theoretical framework of Pereira et al. (2017) [7]. In contrast to the conventional 15-Minute City research, including Moreno et al. (2021) [2], which focuses on the combination of land uses and adding facilities, this paper employs quantitative modeling to highlight the fact that big-scale facilities are subject to both land and financial limitations in the current peripheral urban areas. The introduction of a "Sustainable Mobility Guarantee" (SMG), especially when active transport links are optimized and simulated micro-circulation feeder services are developed using available transport assets, provides a more plausible and affordable way of space optimization. The result resembles the claim made by Shibayama and Laa (2024) [5] about the SMG being a macro-policy mechanism and applies it to the micro-level living circle planning process through a repeatable scenario-based framework.

B. Attribution of Differences and Mechanism Explanation

Why the High SMG scenario decreases the Gini index can be explained by the fact that flexible micro-circulation feeder assumptions could partially alleviate the rigid constraints of conventional public transport by bringing about modeled spatio-temporal compression of scattered outer residential areas with central transportation centers. It means that increasing spatial unit mobility of those who are at a disadvantage can be used as a form of compensation to address spatial mismatch in resource allocation. Moreover, the findings indicate a synergy between the optimization of active transport and improving access to transit whereby walking network improvements increase the effective catchment of bus stops and possibly enhance the marginal gains of adjustments related to transit.

C. Practical Value and Planning Implications

The structure created in this research offers the urban planner a fresh outlook on decision-making: as the development of the "15-Minute City," urban planners must not blindly seek to put facilities everywhere but must create a dual-drive system of "Facility Layout + Mobility Guarantee." Micro-renewals may improve the experience of walking in financially robust core areas, whereas low-cost improvements to public transit access and micro-circulation feeder services using available resources should be given priority in financially constrained and population-dispersed peripheral areas so that governments may achieve their duties to provide a baseline mobility guarantee to their populations, thus ensuring that low-income groups do not become trapped in a state of transport poverty [23].

VIII. Conclusion

A. Core Findings

On the basis of the "15-Minute City" concept, this paper proposes the Sustainable Mobility Guarantee (SMG) and develops a low-cost and replicable spatial optimization system that incorporates multi-modal accessibility modelling (enhanced 2SFCA) and spatial equity measuring (Population-Weighted Gini Index). The analysis based on the demonstration of the problem with the help of publicly available data leads to the conclusion that there is a serious travel inequity in the modern urban peripheries, with a hypothetical Gini index equal to 0.42. The simulation of improved transportation guarantee plans such as the optimization of active transport, development of transit access, and the assumption of micro-circulation feeders may greatly reduce the calculated spatio-temporal distances by 34% and minimize the regional Gini index to 0.28 and ultimately close the spatial deprivation gap between the center and the periphery.

B. Limitations and Future Outlook

The given work has limitations. Firstly, the model is based mainly on fixed POI, open network, and schedule data that enhances the reproducibility but it is unable to reflect the effects of dynamic traffic congestion (peak-hour delays) on real travel times. Secondly, the research does not distinguish the micro-level differences between the speed of travel and mode choices of people of varying ages including the elderly and young adults since these types of individual-level information are hard to collect and could decrease reproducibility.

The possible directions of future research are: (1) using repeated public travel time measurements or open data on transit operations to develop dynamic models of assessing accessibility; (2) adding together aggregated and anonymized demographic heterogeneity to investigate more sophisticated approaches to mobility assurance in an aging population; and (3) synthesizing freely available unit-cost estimates with Cost-Benefit Analysis (CBA) in order to examine viable investment portfolios in various transportation guarantee scenarios under realistic financial conditions.

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AVAILABILITY OF DATA

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AUTHOR CONTRIBUTIONS

Shujie Xie contributed to the conceptualization of the study, literature review, research framework development, data organization, scenario analysis, and original manuscript drafting. Guohua Tan contributed to the refinement of the research design, methodological guidance, result interpretation, manuscript review and editing, and overall supervision of the study. Both authors contributed to the discussion of the findings, approved the final version of the manuscript, and agreed to be accountable for the content of the work.

COMPETING INTERESTS

The authors declare no competing interests.