Potential Impacts of Shared Bike-Transit Integration on Equity in Job Accessibility

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Samenvatting

Het verbeteren van de bereikbaarheid is een van de belangrijkste doelstellingen van het vervoersbeleid. Bereikbaarheid is echter niet altijd gelijk verdeeld door verschillen in landgebruik, vervoersystemen en individuen. Wanneer mensen onvoldoende toegang hebben tot essentiële activiteiten, verhoogt dit het risico op sociale uitsluiting (Lucas et al., 2016), en daarom is het essentieel om bereikbaarheid eerlijk te verdelen via keuzes in het Daily Urban Network, waarbij ruimtelijke keuzes en keuzes in het mobiliteitssysteem op elkaar afgestemd worden. De afgelopen jaren is deelmobiliteit steeds populairder geworden om meer flexibiliteit te bieden in het voor- en natransport van multimodale reizen (Rongen et al., 2022).

Een analyse van de bereikbaarheidsongelijkheid kan een basis bieden voor het vervoersbeleid om prioriteit te geven aan de groepen die onvoldoende toegankelijkheid ervaren. Huidig onderzoek negeert echter de variatie in bevolkingsgroepen, waardoor de bereikbaarheid van groepen die ver onder het gemiddelde zitten, niet in beeld komt. Bovendien voert het meeste onderzoek de ongelijkheidsanalyse uit vanuit een utilitaiair perspectief, wat geen antwoord geeft op de vraag of mensen voldoende bereikbaarheid hebben om volledig deel te nemen aan de maatschappij. Daarom is voorgesteld om de beoordeling te verschuiven naar een sufficiëntie-analyse (Martens et al., 2022), ofwel een toets of alle inwoners een voldoende niveau van bereikbaarheid hebben..

In de context van de Nederlandse fietscultuur zou de integratie van deelfietsen met openbaar vervoer een effectieve interventie kunnen zijn om de toegankelijkheid voor groepen die afhankelijk zijn van openbaar vervoer te verbeteren en rechtvaardigheid in het vervoerssysteem te bevorderen. Er is echter nog steeds geen onderzoek gedaan naar de effecten van de integratie van deelfietsen en het openbaar vervoer op rechtvaardigheid door gebruik te maken van het sufficiëntie principe. Bovendien zijn de voordelen van deelfietsen op de bereikbaarheid van banen, vooral bij het natransport, nog niet voldoende onderzocht.

Om deze hiaten in het onderzoek op te vullen, past deze studie de sufficiëntie benadering van Karel Martens (Karel Martens, 2017) en het IKOB-model van Hans Voerknecht (Hans Voerknecht, 2021) toe op de Vervoerregio Amsterdam. Het doel is om te onderzoeken hoe gedeelde fiets-transit integratie de bereikbaarheid van banen voor verschillende bevolkingsgroepen en de rechtvaardigheid van het hele transportsysteem kan beïnvloeden. De uitkomsten zullen waardevolle inzichten opleveren voor het creëren van een rechtvaardiger transportsysteem in de Vervoerregio Amsterdam.

Introduction

Research Background

The focus on transport policies has shifted from "mobility" to "accessibility" over the past two decades (Ryan & Pereira, 2021). Mobility measures the ease of moving on the network, while accessibility measures the ease of reaching desired destinations (Levinson & Wu, 2020). Accessibility results from the interaction between land use, transport system and individuals (Pereira et al., 2017). It is not always equally distributed due to the inherent differences in these three elements. Insufficient accessibility represents limited opportunities for essential activities, resulting in transport-related social exclusion risks (Di Ciommo & Shiftan, 2017; Fransen & Farber, 2019; Lucas et al., 2016; van Wee & Geurs, 2011). Therefore, accessibility has become an indicator widely used in equity assessment for a transport policy (Di Ciommo & Shiftan, 2017; Lucas et al., 2016).

Besides efficiency and effectiveness, a sustainable transport policy should be equitable (Young & Tilley, 2006). Therefore, providing equitable access to social and economic opportunities has recently received increased attention as one of the primary goals of a transport system (Chinbat et al., 2023). Unlike the similar term "equality", which implies treating everyone equally irrespective of the difference, equity is a moral judgement (González et al., 2022). However, how equity should be defined, how to distinguish the groups for analysis, and which equity indicator and measure to be selected to evaluate the level of equity make the equity analysis highly complex (van Wee & Geurs, 2011). Furthermore, different equity principles have different standards for evaluating equity, which can result in conflicting outcomes because a policy may be regarded as equitable when evaluated one way but inequitable when evaluated another way (Camporeale et al., 2019; van Wee & Geurs, 2011).

Due to the unequal spatial distribution of opportunities and the transport system itself between the different urbanised contexts, as well as the different socioeconomic characteristics, abilities and preferences of individuals, unavoidable inequalities in accessibility can often be observed between different groups, regions and transport modes (Boarnet et al., 2017; Chinbat et al., 2023; Pritchard, Stępniak, et al., 2019a; Qin & Liao, 2022; van der Veen et al., 2020). Since the unequal distribution of benefits and costs is inevitable, Karel Martens stated that "*a fair transportation system provides all persons with a sufficient level of accessibility under most, but not all, circumstances*" (Karel Martens, 2017). Car ownership has been argued as the most influential factor in improving access levels as cars provide superior accessibility than other transport modes in nearly all circumstances (Karel Martens, 2017; Pritchard, Stępniak, et al., 2019b; Qin & Liao, 2022). However, promoting car ownership does not align with environmental goals, and the low-income and disadvantaged groups who are the most transit-dependent often have limited access to their desired activities because they cannot afford a car.

In recent years, shared mobility services have been introduced to encourage the multimodal trips of travellers by providing flexibility in their first/last-mile segments (Rongen et al., 2022). Therefore, implementing multimodal hubs is gaining popularity as it can improve travellers' accessibility and potentially promote the transport system's equity (Frank et al., 2021; Graf et al., 2022; Org, n.d.). Compared to the existing Park + Ride (P+R) facilities that mainly benefit people who already have car access, integrating shared bikes with public transport stations could be an effective intervention to enhance the accessibility for people without car access and promote equity in the transport system. Even though some research has investigated the impacts of integration of bike and transit from the equity perspective, most research evaluated the equity in accessibility from the egalitarian perspective by identifying the disparities between different transport modes or regions, which has been criticised by (Martens et al., 2022), who suggested that the equity assessment should shift from disparity analysis to sufficiency analysis. It was explained that disparity analysis might be problematic as it fails to answer whether people are provided with a basic level of accessibility that allows them to participate in society fully. In addition, it often ignores the heterogeneity within the aggregated groups.

Amsterdam Transport Region (Vervoerregio Amsterdam) wants to promote an equitable transportation system where everyone can easily participate in social life to satisfy their needs. As the benefits and burdens of a transport policy are not evenly distributed, accessibility and equity analysis can help urban planners or policymakers understand how interventions would impact the accessibility for different population groups and the equity level of the whole transport-land use systems. Then transport policy can prioritise the groups experiencing unfair accessibility based on the result of analysis. Access to jobs is one of the most important activities in individuals' daily lives, together with education and health care services. However, most people do not have freedom in choosing their employment locations, which means the transportation systems largely determine the ability to reach the workplaces. Therefore, this thesis will investigate the impacts of shared bike-transit integration on equity in job accessibility to help create a more equitable transport system in the Amsterdam Transport Region.

Research Gaps

1. Research on the impacts of shared bike-transit integration on equity using the sufficientarian principle is still lacking.

2. The benefits of shared bikes on the equity in job accessibility, particularly at the egress-side, have not been thoroughly explored.

Research Objectives

To address these research gaps, this study will apply the sufficientarian approach proposed by (Karel Martens, 2017) and the IKOB model proposed by (Hans Voerknecht, 2021) to the Amsterdam Transport Region. The objective is to investigate how integrating shared bikes and transit can impact job accessibility for different population groups and the equity of the whole transport system. We specifically focus on investigating the impacts on the groups who cannot access cars. Absolute judgements about whether equal or not of the transport system will not be made. Instead, the results of this evaluation will be used to develop recommendations for promoting equity in the Amsterdam Transport Region. In order to achieve the objective, the main research and five sub-research questions are proposed as follows.

Research Question

Main research question: How does shared bike-transit integration impact job accessibility for commuters who cannot access cars and the equity of the whole transportation system in the Amsterdam Transport Region?

Sub-research question 1: How can we define equity in relation to job accessibility?

Sub-research question 2: What factors are relevant in evaluating equity in job accessibility?

Sub-research question 3: How does shared bike-transit integration affect accessibility, and how to calculate its accessibility?

Sub-research question 4: How can the potential impacts of shared bike-transit integration on equity be evaluated?

Sub-research question 5: What are the potential implications of the outcomes of creating a more equitable transportation system in the Amsterdam Transport Region?

1. Research Methodology

In order to assess the equity in job accessibility in the Amsterdam Transport Region, the approach proposed by (Karel Martens, 2017) will be applied as the guideline for equity evaluation. Additionally, the IKOB model proposed by (Hans Voerknecht, 2021) will be used to differentiate the population groups and calculate their potential accessibility. The accessibility and level of equity distribution will be visualised in ArcGIS.

1.1 Equity Evaluation: Sufficientarian Approach

The concept of incorporating fairness into transport planning has been underpinned from theoretical and practical perspectives in Karel Martens's Book "Transport Justice: Designing Fair Transport Systems" (Karel Martens, 2017). Firstly, he argued that accessibility is a better conceptualisation of the transport good than potential mobility. Secondly, instead of disparity analysis, he argued that transportation justice is about providing all persons with sufficient accessibility under most circumstances, irrespective of the differences. Thirdly, he developed a new analytical framework for designing fair transport systems using a new fairness index based on accessibility and potential mobility indicators. Contribution to the overall accessibility deficiency can be identified based on the population whose accessibility is lower than a predefined sufficiency threshold. Finally, he also proved this method by applying it in the case of the Amsterdam region.

This evaluation methodology has been practised by other researchers and confirmed its applicability in identifying groups suffering from unfair accessibility. For instance, (van der Veen et al., 2020) applied this method to identify the differences in accessibility between population groups with different mode availability, time of day and location in the case of Rotterdam. Moreover, (Zweers, 2023) investigated the impact of transport affordability on job accessibility for low-income and unemployed households in the Parkstad region.

Methodology Steps

The sufficientarian approach proposed by Karel Martens has totally 10 steps. However, this research will be limited to the first seven steps of the transportation planning process. As some steps are highly correlated in Karel Martens's evaluation framework, all seven steps are organised into 4 steps: (1) Differentiate the population groups; (2) Identify accessibility insufficiency for different population groups; (3) Assess the severity of accessibility insufficiency for different population groups. (4) Identify the causes of accessibility shortfalls and propose interventions. Among the steps, the distribution of population groups and accessibility calculation will be carried out using the IKOB model.

Measurement

- Accessibility and Potential Mobility Index (PMI)

Accessibility cannot provide direct information about to what extent the transportation system contributes to accessibility as it results from the transportation system, land use, and individuals' characteristics (Pereira et al., 2017). Therefore, it is necessary to complement accessibility measurement with an indicator that can only indicate the contribution of the transport component to accessibility. Karel Martens proposed a measure called the Potential Mobility Index (PMI), which is expressed as the quotient of the Euclidean distance and the travel time on the transport network between origin and destination. PMI is suitable for determining the contribution of the transportation system to accessibility as it captures the impact of both speeds on the links of the transport network, as well as the network structure. The PMI for a specific mode in a specific zone is expressed as:

$$PMI(im) = \frac{1}{n} * \sum_{i=1}^{n} \frac{d(i,j \dots n)}{T(i,j \dots n)} \tag{1-1}$$

Where $PMI(i)$ is the average aerial speed for zone i and mode m, $d(i,j \dots n)$ is the aerial distance between zone i and zone j, and $T(i,j \dots n)$ is the travel time of mode m on the transport network between zone i and zone j.

Subsequently, a coordinate system was constructed, including potential mobility and accessibility simultaneously. By setting thresholds of potential mobility and accessibility, this coordinate system can identify the population groups suffering from limited accessibility because of the transportation system. Figure 1 shows an adapted framework based on the original work.

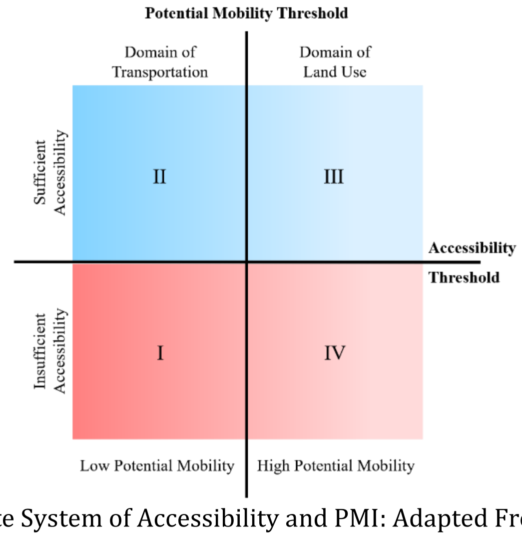

Figure 1: The Coordinate System of Accessibility and PMI: Adapted From (Karel Martens, 2017)

Horizontally, groups in the blue area indicate sufficient accessibility, while the red area means groups are suffering from accessibility shortfalls. Vertically, the darker the colour, the more relevant it is to the transportation system's impact. For instance, insufficient accessibility for groups located at the bottom-left area (Quadrant 1) is largely caused by a poorly functioning transportation system. However, if groups in the bottom-right area (Quadrant 4) have sufficient potential mobility but still experience insufficient accessibility, the influence of land-use-related factors is predominant.

- Accessibility Fairness Index (AFI)

Except for identifying groups who are experiencing accessibility insufficiency, Karel Martens also proposed an index to represent the level of fairness of a transportation system, the Accessibility Fairness Index (AFI). AFI indicates the severity of accessibility deficiency, the larger share of the population below the sufficiency threshold value, and the unfairer transportation system. As AFI distinguishes the groups within the population, it is possible to determine the contribution of each population group to the overall level of accessibility insufficiency. Therefore, AFI is also beneficial for policymakers to prioritise policies. AFI for a specific region is expressed as:

$$AFI(r) = \frac{1}{N}\sum_{i=1}^{q} n_i * \left(\frac{z - y_i}{z}\right)^2 \quad (1\text{-}2)$$

Where N is the total population in region r; q is the number of groups in region r experiencing accessibility levels below the sufficiency threshold z; n_i the size of the $i-th$ group in number of persons; and y_i is the accessibility level experienced by the $i-th$ group below the sufficiency threshold z.

1.2 Accessibility Measurement: IKOB Model

Integrale Kijk Op Bereikbaarheid (IKOB) model was proposed by (Hans Voerknecht, 2021) based on the theoretical accessibility of (Hansen, 1959) and (Levinson & Wu, 2020). The IKOB model can calculate potential accessibility in a more general way by classifying groups according to their travel motivation, mode availability and preferences. Furthermore, all combinations of transport modes can be modelled in the IKOB model using a supernetwork approach. Therefore, it can be used to calculate the potential accessibility for different population groups by different transport modes. The IKOB model has several advantages compared to traditional models:

1. Firstly, instead of one average measure for all, the IKOB model calculates more realistic accessibility by distinguishing different population groups based on their heterogeneity in car ownership, mode preference and income level. Furthermore, employment has been classified into different categories based on income classes.

2. Secondly, the IKOB model considers the rewards of the destination's proximity by using the travel time decay curve, thus providing more realistic results. It can overtake the limitation of border effects in the isochrone accessibility measure, which assumes all trips within a particular time or distance equally.

3. Thirdly, the IKOB model considers the effect of competition within the demand by integrating into the population when calculating potential accessibility. If someone can reach a few jobs in a specific area, but few people live there, the relative accessibility of jobs may not be too bad.

4. Lastly, the IKOB model includes multiple chain trips through the supernetwork. Therefore, the accessibility benefits of multimodalities can be fully included in the IKOB model, which is not considered in traditional models.

The potential accessibility calculation in the IKOB model is summarised into 4 steps: (1) Groups Distribution; (2) Experienced Travel Time; (3) Weights for Unimodality and Multimodality; (4) Potential Accessibility. Before running the IKOB model, data on individuals, transport and land use should be prepared as input files. Figure 2 illustrates the overview of steps, and the algorithm in each step will be explained in the following subsections.

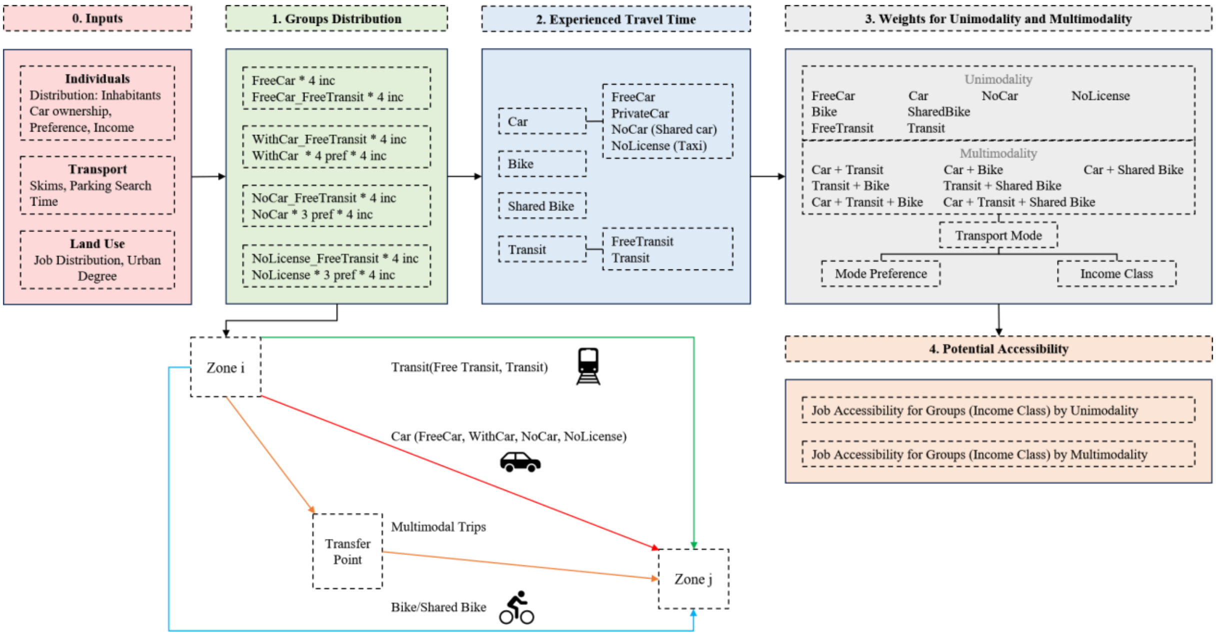

Figure 2: Steps Overview of the IKOB Model

Step 1: Groups Distribution

Population are classified into 60 groups according to their capabilities and preferences: (1) Car ownership: With Car (Free Car, Not Free Car, Free PT, Not Free PT); No Car (Free PT, Not Free PT); No License (Free PT, Not Free PT); (2) Mode preference: car, public transport, bicycle and neutral; (3) Income class: High, Middle-high, Middle-low, Low. The overview of group classification is shown in Figure 3.

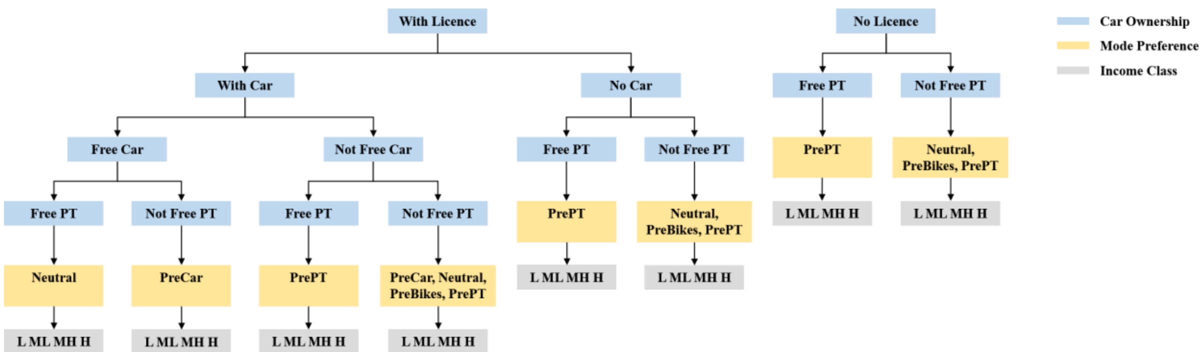

Figure 3: Overview of Groups Distribution

- Determining Income Class

The percentages of income classes per zone P_{iz} and the urbanisation degree of zone S_z are derived from the CBS district and neighbourhood data.

- Determining Car Ownership

Car ownership is divided into 8 categories: (1) With Car (Free Car, Not Free Car, Free PT, Not Free PT); (2) No Car (Free PT, Not Free PT); (3) No License (Free PT, Not Free PT). The percentage of car ownership, excluding Free Car and Free PT is determined based on the urbanisation degree and income class from CBS data. The percentage of the population with free car per income class are accessed from Vereniging Zakelijke Rijders (VZR), and 12% of the cars are company cars. The percentage of people with Free PT per urbanisation degree is estimated based on NS data, and 3% is used in the IKOB Model.

The "theoretical" car ownership $AZ_{z,theor}$ (With Car), $GA_{z,theor}$ (No Car) and $GR_{z,theor}$ (No License) are calculated:

$$AZ_{z,theor} = \sum_i AZ_{si} * P_{iz} \tag{1-3}$$

$$GA_{z,theor} = \sum_i GA_{si} * P_{iz} \tag{1-4}$$

$$GR_{z,theor} = \sum_i GR_{si} * P_{iz} \tag{1-5}$$

Where AZ_{si}, GA_{si} and GR_{si} are car ownership per urbanisation degree s and income class i for the three groups; P_{iz} is the percentage share of income class i per zone z.

According to the CBS district and neighbourhood data, the actual number of cars per household per zone may be equal to, smaller or larger than the theoretical car ownership. If the actual number of cars per household per zone AA_{hz} is smaller than theoretical car ownership $AZ_{z,theor}$, car ownership per zone AZ_z equals AA_{hz}. Otherwise, AZ_z equals $AZ_{z,theor}$. There, the car ownership per zone per income class AZ_{iz} (With car), GA_{iz} (No car) and GR_{iz} (No License) are then expressed with a correction factor:

$$AZ_{iz} = \frac{AA_{hz}}{AZ_{z,theor}} * AZ_{iz,theor} \tag{1-6}$$

$$GA_{iz} = \frac{1 - AA_{hz}}{1 - AZ_{z,theor}} * GA_{iz,theor} \tag{1-7}$$

$$GR_{iz} = \frac{1 - AA_{hz}}{1 - AZ_{z,theor}} * GR_{iz,theor} \tag{1-8}$$

The ownership of free car per income class i in zone z GrA_{iz} is calculated as:

$$GrA_{iz} = GrA_i * AZ_{iz} \tag{1-9}$$

- Determining Preferences

Preferences for transport modes per urbanisation degree for those who own a car and those who do not own a car are from OVIN and survey by the municipality of Amsterdam. For "Free Car", "Free PT" and "Free Car and Free PT" groups, it is logical that there are no combinations of mode preference. The decision rule for preference are summarised: (1) For groups of No Car and No License, they do not have a preference for a car; (2) For groups of No Car and No License, but Free Transit, their preference is transit; (3) For groups of Free Car and Free Transit, their preference is neutral; (4) For groups of Free Car without free transit, their preference is car; (5) For groups with private car and free transit, their preference is transit.

Step 2: Experienced Travel Time

The experienced travel time for a certain group with a certain transport mode takes into account "pure" travel time and travel costs. As travel costs are valued very differently per population group, the sensitivity of costs is determined by the travel motive and income class. The experienced travel time for different transport modes and income classes is expressed below:

$$ER_{ghbv} = R_{hbv} * TVOM_i(Ktotal_{ghbv}) \quad (1\text{-}10)$$

Where R_{hbv} denotes the "pure" door-to-door travel time between origin h and destination b with transport modes v; $TVOM_i$ is the time value of costs for income class i; $Ktotal_{ghbv}$ is the total costs from origin h to destination b for group g with transport mode v.

- Car (FreeCar, WithCar, NoCar, NoLicense)

For "pure" travel time of car (Parking Search Time + In-vehicle Travel Time):

$$R_{hbcar} = PZA_z + PZV_z + T_{hb,invehicletime} \quad (1\text{-}11)$$

Where PZA_z and PZV_z are the parking search time when arrival and departure in zone z; $T_{hb,invehicletime}$ is the travel time in the vehicle between origin h and destination b.

For total costs of car ((Cost per km + Charge per km) * Distance):

$$Ktotal_{ghbcar} = (Kcost_{g,car} + Kcharge_{g,car}) * A_{hb,invehicletime} + Kpark_{g,car} + Kcordon_{g,car} \quad (1\text{-}12)$$

Where $Kcost_{g,car}$ is the variable costs per km for group g with mode v; $Kcharge_{g,car}$ is the charge per minute for group g with mode v; $A_{hb,invehicletime}$ is the distance in the vehicle between origin h and destination b. $Kpark_{g,car}$ is the total parking costs per trip for group g with mode v. $Kcordon_{g,car}$ is the cordon charge for group g with mode v.

Both variable costs and charge of the Free car are null; Variable costs of the car is 0.16/km; Variable costs of the shared cars is 0.3 €/km, and charge is 0.05 €/min; Variable costs of the taxi is 2.4 €/km, and charge is 0.4 €/min.

- Transit (FreeTransit, Transit)

For "pure" travel time of transit:

$$R_{hbtransit} = VT_{ho} + T_o + T_{ou,invehicletime} + W + NT_{ub} + T_u \quad (1\text{-}13)$$

Where VT_{ho} is the transit pre-transportation time from origin h to boarding stop o; T_o is Transfer time on boarding station o; $T_{ou,invehicletime}$ is the travel time in the vehicle between origin o and destination u; W is the waiting time due to transfers; NT_{ub} is the transit post-transportation time from exit station u to destination b; T_u is the transfer time at exit station u.

For total costs of transit:

$$Ktotal_{ghbtransit} = Kcost_{g,transit} * A_{ou,invehicletime} + K_{opstap} \quad (1\text{-}14)$$

Where $Kcost_{g,transit}$ is the variable costs per km for group g with transit; $A_{ou,invehicletime}$ is the distance in the vehicle between boarding stop o and exit stop u; K_{opstap} is the boarding rate in transit.

For "FreeTransit" groups, both the variable costs and boarding rate are null. Otherwise, variable costs $Kcost_{g,transit}$ is 0.121 €/km and boarding rate K_{opstap} is 0.75 €.

- Private Bike

For the "pure" travel time of private bikes:

$$R_{hbbike} = T_{hb,invehicletime} \quad (1\text{-}15)$$

The variable costs of the bike have been set at 0.

- Shared Bike

The "pure" travel time of shared bikes equals the travel time of private bikes. For total costs of shared bike:

$$Ktotal_{ghbsharedbike} = Kcost_{g,sharedbike} \quad (1\text{-}16)$$

Step 3: Weights for Unimodality and Multimodality Measurement

The IKOB model uses the travel time decay curve to reward the destination's proximity. Therefore, destinations with a shorter experienced travel time weigh relatively more heavily than destinations with a longer experienced travel time. Different individuals will be willing to pay for different transport modes because of differences in preferences and income classes. Except for experienced travel time, weight is also determined by groups with a specific preference from a specific income class by a specific transport mode with a specific motivation.

- Weights for Unimodal Trips

The weight G_{ghbvm} of a trip from origin h to destination b for group g by transport mode v with motive m is:

$$G_{ghbvm} = RTV_{pvm}\left(ER_{ghbv}\right) \quad (1\text{-}17)$$

Where RTV_{pvm} is the travel time decay function of preference p, transport mode v and motive m ; ER_{ghbv} is the experienced travel time for group g between origin h and destination b with transport mode v.

The travel time decay function is:

$$RTV_{pvm} = w * \frac{1}{1 + e^{\alpha*(-\omega+t_{erv})}} \quad (1\text{-}18)$$

Where ω is the turning point; α is the steepness of the curve; w is the weighting of the value; t_{erv} is the experienced travel time.

- Weights for Multimodal Trips

The maximum weight across the single transport modes per origin-destination cell will be taken as the weights for multimodal trips. The weights for multimodal trips for group g origin h destination b are expressed as:

$$GC_{ghbm} = Max(v)G_{ghbvm} \tag{1-19}$$

The travel time decay parameters reflect these differences by adjusting the curve's turning point and steepness. However, these parameters are subjective and require empirical data to be calibrated and validated. In the IKOB model, they have been chosen based on expert judgement. The weighting factors were calibrated/validated by assessing whether the chosen values would more or less reproduce the shares per target group as in the Onderzoek Verplaatsingen in Nederland (OViN). The travel motivation, transport modes and preferences determine the values of parameters in the travel time decay curve. The travel time decay curve for commuting motivation for different transport modes and preferences is illustrated in Figure 4.

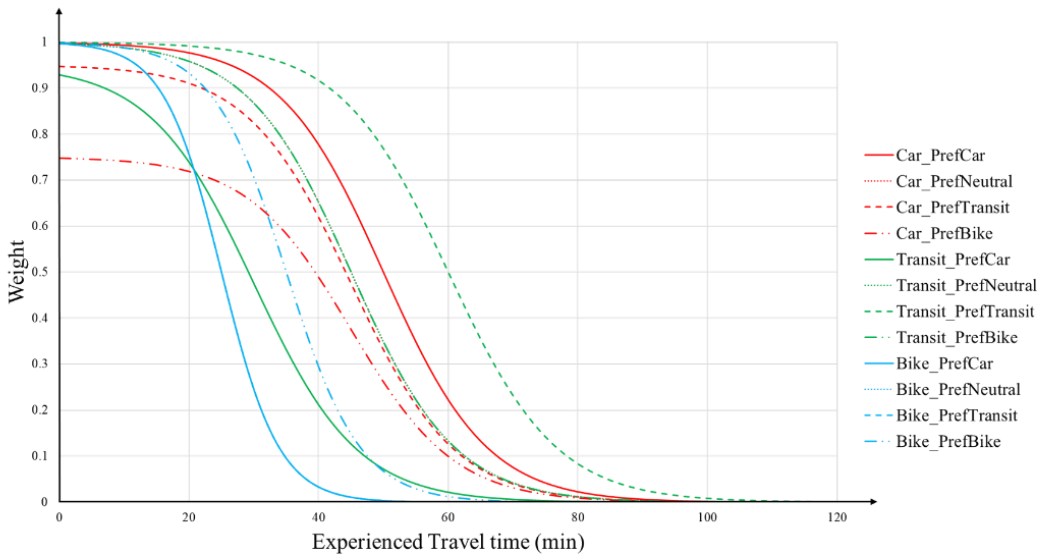

Figure 4: Travel Time Decay Curve Based on Transport Modes and Preferences

Step 4: Potential Accessibility

Potential accessibility in the IKOB Model is measured by the number of opportunities can be reached from a particular zone/region (urbanisation degree) for a certain group (income class, mode preference, car ownership) by a certain unimodality or multimodality (public transport, car, bike, shared bike, multimodal trips) with a motive (Work, daily shopping/healthcare, non-daily shopping/education), at a certain time of day (morning peak, rest of day, evening peak).

Total number of jobs for group g in origin zone h for transport mode (combination) v is:

$$B_{ghv} = \sum_{b} V_{gh} * G_{ghbvm} * A_{ib} \tag{1-20}$$

Where V_{gh} is the size of group g in origin zone z; A_{ib} is the number of jobs for income class i in destination zone z; i is the income class to which group g belongs.

The number of jobs per income class i in origin zone h for mode (combination) v is:

$$B_{ihv} = \sum_{g} B_{ghv} \tag{1-21}$$

When we want to determine the total accessibility in a region (municipality, sub-municipality, province, etc.) for income class i in region r for mode of transport (combination) v:

$$B_{irv} = \frac{\sum_h in\ r B_{ihv} * I_{ih}}{\sum_h in\ r I_{ih}} \tag{1-22}$$

Where I_{ih} is the share of inhabitants in income class i in origin zone h.

Potential accessibility by a certain mode is calculated based on the availability-weighted mode optimal access, which means the mode available to a group represents the best option for this group. Taking car-based accessibility as an example, Free Car groups are assumed to choose free car; With Car groups are assumed to choose private car; No Car groups are assumed to choose shared car; No license groups are assumed to choose taxi. The preference and income class information has already been classified in step 2 "Groups Distribution". When calculating the accessibility for a specific group by a specific transport mode, preference and income class will be identified to match the corresponding weights.

1.3 Data Preparation

- Land-use

The distribution of jobs per neighbourhood can be derived from the LISA file (Landelijk Informatiesysteem van Arbeidsplaatsen; Employment register database). The dataset for the urban degree can be obtained from the CBS District and Neighbourhood data.

- Transport

Travel time and distance by transport modes are derived from the regional traffic model VENOM. Euclidean distance matrix per transport mode for sufficientarian approach is generated in ArcGIS.

- Individuals

Inhabitants per income class and number of cars per household are accessed from CBS District and Neighbourhood data. For car ownership: CBS (With car, No car and No license); Vereniging Zakelijke Rijders, VZR (Free car); NS data (Free PT). The mode preference for groups with/without car in different urbanisation degrees are derived from travel research in the Netherlands: Onderzoek Verplaatsingen in Nederland (OVIN) and a survey by the Gemeente Amsterdam.

2. Case Study Area

This report focuses on the municipality of Amsterdam and 14 surrounding municipalities, which are shown in Figure 5. It was selected as a case study because it includes multiple municipalities with different characteristics in urbanisation degree, population composition, employment density and transport services. The resulting different levels of accessibility in various contexts explain the potential reasons for accessibility distribution and give implications for possible interventions for the municipalities to promote a more equitable transport system.

Figure 5 Municipalities in Amsterdam Transport Region

3. Conclusion

Integrating shared bikes with transit could be an effective intervention to enhance the accessibility for transit-dependent groups and promote equity in the transport system. However, no research has been conducted to examine the impacts of shared bike-transit integration on equity using the sufficientarian principle. Moreover, the benefits of shared bikes on the equity in job accessibility, particularly at the egress-side, have not been thoroughly explored. To address these research gaps, this research will apply the sufficientarian approach proposed by Karel Martens (Karel Martens, 2017) and the IKOB model proposed by Hans Voerknecht (Hans Voerknecht, 2021) to the Amsterdam Transport Region. The objective is to investigate how shared bike-transit integration can impact job accessibility for different population groups and the equity of the whole transport system.

This paper only presents the introduction of the project in terms of research background, research gaps, research objective, research questions and research methodologies. The final results will be formulated into the Master's Thesis of Quanyi Wang, a student from Transport & Planning programme of TU Delft. From an academic perspective, this research has the potential to contribute to the discussion on the impacts of shared bike-transit integration on equity in job accessibility. From a practical perspective, it not only contributes to the applicability of the IKOB model, but could help the Amsterdam Transport Region develop a more equitable transport system.

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