

Evaluating Spatial And Social Equity In Public Transport Accessibility: A Case Study Of Melbourne's Inner South East Metropolitan Region

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Abstract. Accessibility measures are widely used to analyse transport equity. However, most studies assume that all reachable opportunities are equally available and therefore overlook competition among users. This limitation is particularly important in high-density inner metropolitan areas, where large populations compete for a finite set of jobs and urban services. This study adopts a competition-adjusted cumulative opportunity measure and applies it to a case study of four service types (employment, education, healthcare and retail) in Melbourne's Inner South East Metropolitan Region. Spatial results are then cross-analysed with socio-economic indicators. The results show that considering competition substantially reduces effective accessibility. The four service types have different accessibility patterns, with healthcare accessibility exhibiting the strongest spatial inequality. A cluster of double disadvantage is also identified in the south-eastern part of the region, where low accessibility coincides with relatively high socio-economic disadvantage. These findings demonstrate that proximity to inner-city do not necessarily ensure equitable access to urban opportunities. By integrating competition-adjusted accessibility with socio-economic analysis, this study offers a diagnostic framework for revealing hidden equity deficits in high-supply metropolitan environments.

Keywords: Public transport accessibility, transport equity, competition-adjusted cumulative opportunity measure.

1. Introduction

1.1 Introduction

In today's urban life, basic services such as employment, education, healthcare and daily consumption are regarded as the fundamental rights of urban residents [1]. When the access to these opportunities is uneven, inequity will arise. It will lead to social exclusion and intergenerational cumulative risks [2]. Therefore, equity has become the main principle of urban governance. Planning professionals need to conduct empirical research to identify which groups in urban areas are disadvantaged, and how these disparities are manifested through daily travel patterns [3, 4].

Travel is not an end in itself, but a means through which individuals gain access to socially and economically valuable opportunities [5]. This understanding lies at the core of debates on transport equity. Public transport (PT), in particular, has long been assigned a public responsibility to support universal travel opportunities and basic mobility rights [3]. However, in mobility-oriented planning frameworks, especially those prioritising network performance and movement efficiency, transport equity has often been interpreted as equal rights to use transport infrastructure rather than the outcomes such use enables [6]. This overlooks a fundamental point that most people travel in order to reach employment, education, healthcare, and other essential opportunities. This is a results-oriented perspective that focuses on whether individuals can actually reach their key destinations within given time and resource constraints [6]. The concept of accessibility therefore has been introduced into transport equity research to assess the extent to which transportation systems support people's participation in urban life [3, 6].

Several methods for measuring accessibility have been developed to evaluate the spatial distribution of urban opportunities and services [7]. These methods are applied across a range of urban planning research contexts, with the shared goal of informing spatial equity assessment. Among them, the cumulative opportunity measure has been widely adopted in urban and transport planning for its

conceptual simplicity and ease of interpretation [8, 9]. Specifically, it quantifies accessibility by counting the number of opportunities reachable within a predefined travel time threshold. However, this approach implicitly assumes that all reachable opportunities are equally available to all users. In practice, many opportunities, such as jobs and school places, have finite capacity and are therefore subject to competition among users. Kelobonye et al. [8] found that when accounting for competing populations, the effective opportunities available to each individual significantly decline. As a result, a newer perspective holds that incorporating competitive factors into accessibility measurement more accurately reflects how opportunities are actually distributed across different spaces and population groups.

1.2 Australia and Melbourne Context

Planning policies across Australian cities have long favoured public transport-oriented approaches and have been committed to addressing transport equity [10]. The reasons are twofold. On the one hand, the long-term urban sprawl and the low-density spatial form have continuously widened the spatial distance between residents and key activity destinations. Travel time and travel costs also increase accordingly [11]. As the feasibility of alternative modes of transportation such as walking, cycling and PT declines, suburban residents have become increasingly dependent on private vehicles [11]. On the other hand, socio-economic disadvantage among urban residents often coincide with spatial remoteness. This further increases the risks individuals face in accessing basic services and exacerbates social exclusion [3]. Together, the focus of transport equity has shifted from whether people can travel to whether they can effectively participate in urban life. Accessibility emerges as a more explanatory analytical principle in Australian urban and transport planning [11]. The Victorian Government institutionalised this concept through Plan Melbourne 2017-2050 as the strategic planning framework for the Melbourne metropolitan region [12]. Specifically, accessibility of daily necessary services is explicitly established as a key urban governance objective and used to guide corresponding urban form and development strategies. In practice, however, spatial disparity in PT accessibility across Melbourne remains persistent. Inner-city areas benefit from dense PT networks, while outer suburbs continue to face significant travel burdens [3, 10].

Existing research has also indicated that spatial disparities in PT accessibility are closely associated with the socio-economic status of an area [10]. Using the Socio-Economic Indexes for Areas (SEIFA), studies have identified a broad centre-periphery pattern in which socio-economically advantaged populations are concentrated in inner urban areas, while more disadvantaged groups are increasingly located in suburban locations [11, 13]. As a result, socio-economic disadvantage often coincides with poorer access to employment, services and PT opportunities [11, 14]. However, these conclusions are derived primarily from metropolitan-scale comparisons and have informed planning responses largely directed towards outer-suburban disadvantage. Much less attention has been given to the distribution of accessibility within high-supply inner metropolitan areas.

1.3 Research Motivations And Research Question

In inner-city areas with high levels of PT supply, dense multimodal transport networks and diverse urban functions tend to coexist [11]. Yet high supply does not necessarily translate into equitable access. In these areas, despite nominally strong PT accessibility, individuals have to compete with a greater number of potential users for limited service capacity [8]. This dynamic remains largely unexamined in existing equity assessments, which tend to treat PT supply as a sufficient proxy for accessibility.

A further gap concerns the scope of opportunity types considered. The analytical focus of existing transport equity research has largely been confined to a single destination category, most commonly employment [8, 15]. Yet other opportunities such as education, healthcare, and everyday retail equally as daily needs for residents, and there are considerable differences in accessibility to different destinations [15]. Thus, the analysis of multiple service types enables a more comprehensive understanding of urban advantage, rather than a result of any particular sector.

Furthermore, studies of transport equity have often examined spatial accessibility and socio-economic disadvantage separately. Accessibility research commonly focuses on the spatial distribution of opportunities and transport services, whereas studies of transport disadvantage tend to emphasise the socio-economic characteristics of affected populations [5, 16]. This separation is particularly problematic in inner metropolitan areas, where high levels of PT provision are frequently assumed to coincide with socio-economic advantage [11]. Consequently, accessibility-based assessments may overlook disadvantaged populations living within nominally well-served areas. A more comprehensive understanding of transport equity therefore requires consideration of both accessibility outcomes and socio-economic conditions [1].

To fill these gaps, this study provides a systematic evaluation of PT accessibility and equity in Melbourne's Inner South East Metropolitan Region (ISEMR), one of Melbourne's high-supply inner metropolitan regions. To capture the distributional characteristics of accessibility under conditions of high demand, the study adopts a competition-adjusted accessibility measure that accounts for the effect of competing users on effective opportunity access [8]. This approach is applied across four essential service types - employment, education, healthcare, and retail - and subsequently integrated into a Composite Accessibility Index (CAI) to assess overall patterns of accessibility inequality. Accessibility outcomes were subsequently cross-classified with socio-economic disadvantage indicators to evaluate the relationship between spatial and social disadvantage. In doing so, this study contributes a more integrated approach to assessing transport equity in high-supply inner metropolitan contexts.

This study is guided by the following research question:

RQ: How is public transport accessibility distributed across Melbourne's Inner South East Metropolitan Region (ISEMR) when opportunity competition is taken into account?

How does competition-adjusted public transport accessibility to employment, education, healthcare, and retail vary across ISEMR? Which areas demonstrate consistently low accessibility across multiple service types?

How do patterns of public transport accessibility correspond with socio-economic disadvantage across ISEMR?

1.4 Overview of the Research

This thesis is organised into seven sections. Following this introduction, Section 2 reviews the literature on transport equity and accessibility measures. Section 3 outlines the study area, data sources, and research methodology. Section 4 presents the accessibility and equity analysis results. Section 5 discusses the findings in relation to existing research and the broader transport equity literature. Finally, Section 6 discusses the implications and limitations of the study, and Section 7 concludes the thesis.

2. Literature Review

2.1 Transport Equity: Theoretical Foundations

2.1.1 From Mobility To Accessibility

Transport equity has been a concern of urban scholars and planners since at least the 1960s [1]. Yet the conceptual basis for its assessment has undergone substantial evolution over time. For much of the twentieth century, transport planning was organised around the principle of mobility. It refers to the ability to move quickly and efficiently through space, typically relying on private vehicles [6, 17]. Under this paradigm, equity was interpreted narrowly as equal rights to use transport infrastructure. Investment decisions were guided primarily by network performance metrics such as vehicle throughput and travel speed, rather than by the outcomes these networks produced [18, 19].

Mobility-based approaches have been increasingly criticised because they fail to consider the opportunities that movement enables [17, 18]. In response, accessibility has emerged as an alternative

framework centred on the ability of individuals to reach desired destinations and participate in everyday activities [6, 20]. This perspective raises questions about who can access services and social activities, and under what conditions. Travel is therefore understood not as an end in itself, but as a means of participating in economic and social life [5].

2.1.2 Distributive Justice In Transport

Transport equity research draws heavily on theories of distributive justice, which concern the fair allocation of social resources and opportunities [1]. Different theories offer contrasting views on how transport benefits and burdens should be distributed and therefore imply different approaches to evaluating equity.

Utilitarian approaches prioritise aggregate welfare and have long shaped transport appraisal through cost-benefit analysis and travel-time savings metrics [1]. Although this approach has informed mainstream transport planning for decades, its limitations from an equity standpoint are well-documented. Due to its focus on aggregate effects, it may justify policies that improve overall well-being at the expense of minority or marginalised groups [1].

Liberal perspectives emphasise individual choice and market allocation [1]. That means consumers can choose their mode of travel based on preferences and affordability [1]. However, because transport systems exhibit substantial externalities and unequal purchasing power, market outcomes do not necessarily provide equitable access to opportunities, particularly for lower-income and mobility-constrained populations [18, 21].

By contrast, Rawls' [22] egalitarianism has a greater influence on the study of traffic equity. He posits that social equity is primarily achieved through two principles. First, the principle of basic liberties, which stipulates that all individuals should equally enjoy fundamental freedoms. Second, the difference principle, which holds that inequalities are justifiable only when they benefit the least - advantaged members of society [22]. Applied to transport planning, Rawls' theory can be divided into two aspects: horizontal equity and vertical equity [3, 23, 24]. Horizontal equity refers to the even distribution of transport systems. It avoids any spatial allocation of transport that favours any individual or group [23]. However, in the case of public transit, certain groups are more likely to rely on such services. For example, low-income individuals commuting by public transportation or carless households [25]. This relates to vertical equity, and they are more susceptible to unfairness in service delivery [21, 24]. Together, these two perspectives constitute complementary viewpoints for assessing transportation equity. Applying both simultaneously is essential for equity analysis.

2.1.3 Social Exclusion And Transport Disadvantage

Social exclusion has become an important concept in transport research. It refers to the systemic processes through which individuals and groups are prevented from full participation in the civic life of their communities [26]. Unlike income poverty alone, social exclusion captures a broader range of disadvantages associated with restricted opportunities, limited social participation and reduced well-being [5]. Research in the United Kingdom first demonstrated how inadequate or unaffordable transport can contribute to these outcomes by creating cumulative barriers to everyday activities and reinforcing existing forms of disadvantage [26]. Such effects are not experienced equally across the population. Low-income households, older adults, people with disabilities and recent migrants are often identified as particularly vulnerable. They are the most dependent on PT and the least able to substitute private vehicle use when services are inadequate [5].

Similar relationships between transport disadvantage and social exclusion have also been observed in Australian cities. Transport disadvantage in Melbourne is concentrated among low-income households, outer suburban residents, and car-free populations [27]. These overlapping disadvantages associates with lower levels of social participation. Furthermore, the specific transport problems, including service unreliability, excessive travel times and high costs, have been shown to have a measurable negative impact on subjective well-being, independent of other socioeconomic factors [3]. In Perth, Ricciardi et al. [28] found that elderly residents, low-income households, and car-free

households all experienced less equitable distributions of PT services relative to the general population.

Critically, however, the relationship between spatial accessibility and social disadvantage is neither linear nor deterministic. Evidence from multiple urban contexts in Canada reveals that socially disadvantaged populations do not always reside in areas of low PT accessibility. Conversely, high spatial accessibility does not guarantee equitable outcomes for all residents within a given area. Foth et al. [29] found that in Toronto, the most socially disadvantaged census tracts actually recorded higher job accessibility by transit and shorter travel times than more affluent areas. A pattern also partially observed by El-Geneidy et al. [23, 24] in the Greater Toronto and Hamilton Area and Montreal. Allen and Farber [30] similarly found that, in aggregate, lower-income neighbourhoods across Canadian cities tend to have better transit accessibility. Yet nearly one million low-income individuals still lived in areas of low access and concentrated particularly in outer suburban locations. These findings reveal the limitations of a single spatial analysis. The overlap between social disadvantage and PT inaccessibility does not always occur systematically. Furthermore, non-spatial barriers, such as travel costs, physical or cognitive limitations, caregiving responsibilities, and safety concerns, also influence actual participation [31]. Therefore, a comprehensive assessment of transport equity requires consideration not only of the spatial distribution of accessibility outcomes, but also of how these outcomes relate to patterns of socio-economic disadvantage.

2.2 Measuring Accessibility

2.2.1 Measurement Typology

Accessibility refers to how easily travelers can reach their destination [32]. Since Hansen's [33] seminal work linking accessibility to the spatial distribution of opportunities, the concept has become central to transport and land-use research. Subsequent decades of theoretical and empirical development have produced a rich body of literature on how accessibility should be defined and measured. Geurs and Van Wee [7] classify existing accessibility measures into four broad types. The first type is infrastructure-based measures, which focus on the supply capacity of transport infrastructure. In transport planning, the approach is often used to assess the density of roads or the coverage of transport, without explicitly considering the distribution of destination opportunities [7]. In contrast, location-based measures consider the number or value of destinations reachable from a given origin within a specific travel cost or time threshold [32, 34]. The third type are person-based measures, which are rooted in temporal geography. They incorporate individual-level constraints and activity schedules to reflect the reality that accessibility varies across people and across time [4, 7]. Finally, utility-based measures apply random utility theory to model the benefit or utility that individuals derive from access to a set of opportunities [7]. They capture the substitutability and attractiveness of different destinations in addition to their mere reachability.

Each of these measure types involves trade-offs between theoretical rigour and practical applicability [7]. Specifically, infrastructure-based measures are simple to calculate but provide limited insight into whether residents can actually reach the services they need. Person-based and utility-based are theoretically complex and sensitive to individual differences, typically requiring detailed travel logs and behavioural models [34, 35]. This makes them difficult to apply at metropolitan scales and unsuitable for routine planning. In contrast, location-based measures occupy a middle ground: they are sufficiently grounded in the spatial outcomes of transport systems to yield meaningful equity insights [32]. Critically, their location-based orientation is well-suited for studying varies in service access within urban space. Multiple destination types can be directly compared within a consistent analytical framework. For these reasons, location-based measures, and in particular the cumulative opportunity measure, have become the dominant approach in applied transport equity research [8]. They also form the methodological foundation of this study.

2.2.2 Cumulative Opportunity Measures: Strengths And Limitations

The cumulative opportunity measure defines accessibility as the number of opportunities that can be reached from a given origin within a specified travel time threshold [36]. It can be expressed as:

$$A_i = \sum E_j c \quad (1)$$

Where A_i is the accessibility of origin zone i ; E_j is the number of opportunities at zone j ; and c is a constant, equal to 1 if travel time within the given threshold, and 0 otherwise.

Although the cumulative opportunity measure is useful in practice, it has been subject to well-documented criticisms. The most fundamental concerns the arbitrary selection of the travel time threshold. It counts all destinations within the threshold equally, and excluding all destinations beyond it entirely [7]. The results therefore are highly sensitive to the chosen cutoff value, and there is no principled method for determining what threshold is most appropriate [9]. A second limitation concerns the implicit assumption that all reachable opportunities are equally available to all users [8, 37]. The supply of opportunities is treated as infinite, thus giving rise to the concept of competition in accessibility.

2.2.3 Accessibility Under Competition

Competition arises when multiple individuals seek access to the same set of opportunities. Ignoring this effect leads to an overestimation of accessibility, especially in densely populated urban areas [8, 37].

One approach to considering competition is the two-step floating catchment area (2SFCA) method, proposed by Luo and Wang [38] in the field of healthcare accessibility. It proceeds in two steps. First, the supply-demand ratio is calculated by dividing the available supply for each destination by the total population of its catchment area. Second, these ratios are summed across all destinations reachable from a given residential location within the time threshold to produce the overall accessibility score. However, its application has remained largely confined to healthcare accessibility, also does not readily generalise to multi-service transport equity frameworks operating at the metropolitan scale [8, 39].

Kelobonye et al. [8] proposed an alternative competition-adjusted cumulative opportunity measure capable of assessing transport equity across multiple service types. They argued that in contexts where opportunities are capacity-constrained, competition among residents for a limited supply of destinations renders traditional accessibility indicators unreliable [8]. In high-density areas, potential demand far exceeds the supply of opportunities, thereby reducing the actual accessibility of each individual [8, 40]. This method divides the available opportunities at each destination by the total population that can reach it within the same threshold. The accessibility is expressed as the number of opportunities effectively available per person, rather than the gross number nominally within reach [8]. Using three service types (employment, education and retail) in the Perth metropolitan area as examples, their study demonstrates that introducing competition significantly altered accessibility outcomes, particularly in high-dense areas with concentrated population and opportunities [8].

2.2.4 Multi-service Accessibility

Despite the breadth of the transport equity literature, its empirical focus has been notably narrow in terms of the destination types considered. The majority of accessibility studies have concentrated on employment as the primary [15]. This emphasis is not without justification, as employment accessibility has direct implications for economic participation, income generation and social inclusion, and travel to work represents the dominant journey purpose in most metropolitan transport planning frameworks [41, 42]. However, different types of opportunities are equally important [8].

Education represents one of the most critical non-work trip purposes. It influences intergenerational mobility and human capital accumulation [43, 44]. Healthcare services represent another essential destination type, as access to healthcare is fundamental to health outcomes and quality of life. Neutens [39] reviewed the growing body of literature on healthcare accessibility from a transport geography perspective, showing that disparities in PT-based access to health services are

both spatially significant and socially differentiated, with disadvantaged populations consistently facing greater barriers to healthcare utilisation. Meanwhile, retail facilities are crucial for residents' access to daily necessities, directly influencing household expenses, dietary health, and overall well-being [45, 46].

Critically, research examining on multiple service types has found that the accessibility patterns associated with different destination types do not necessarily coincide. The key finding of Kelobonye et al. [8]'s study of employment, education, and retail in the Perth was the significant differences in their accessibility and spatial distribution. Cui and Levinson [15] hold a similar view, arguing that the overall value of a region depends on the accessibility of multiple opportunities. Accessibility to a single service cannot reveal the full picture of urban spatial structure and may even lead to misunderstandings of spatial equity. Together, these evidence provide a strong methodological basis for multi-service accessibility analysis in transport equity research.

3. Methodology

3.1 Study Area

The Inner South-East Metropolitan Region (ISEMR) was selected as the study area for this study (see Figure 1). It is one of the six metropolitan regions under the Plan Melbourne 2017-2050 land use framework, in close proximity to Melbourne's Central Business District (CBD). The region encompasses four Local Government Areas (LGAs): Boroondara, Stonnington, Glen Eira, and Bayside, and comprises 34 Statistical Areas Level 2 (SA2s), as shown in Figure 2.

The ISEMR occupies a distinctive position within Melbourne's metropolitan structure. Unlike the CBD, which is dominated by commercial and employment functions, or outer metropolitan areas that are more uniformly characterised by lower PT provision, the ISEMR contains substantial variation in urban form, population composition and accessibility conditions [3, 47, 48]. The region includes both high-density mixed-use centres and established middle-suburban residential areas, making it well suited for examining how accessibility and equity vary within a high-supply inner metropolitan context.

The region is also served by an extensive multimodal PT network comprising rail, tram and bus services [47]. Nevertheless, local planning documents suggest that parts of the system are approaching capacity and facing issues of ageing assets [47]. Increasing traffic congestion challenges the reliability of future transport services. These pressures have prompted local governments to commit to network renewal with an explicit focus on enhancing PT provision. Together, these context further highlight the importance of accessibility-based assessment in guiding ISEMR planning decisions.



Figure 1. Location of the Inner South East Metro Region by DELWP [47]

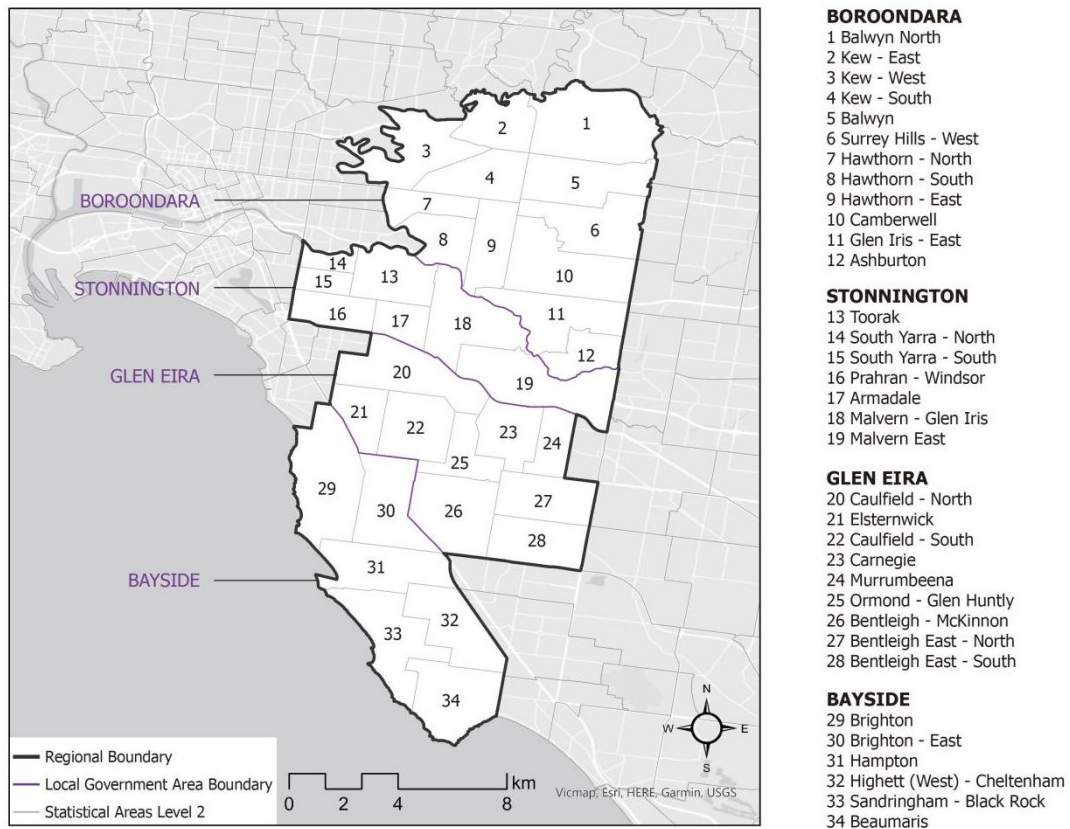


Figure 2. 34 SA2s within Inner South East Metropolitan Region

3.2 Competition-Adjusted Cumulative Opportunity Method

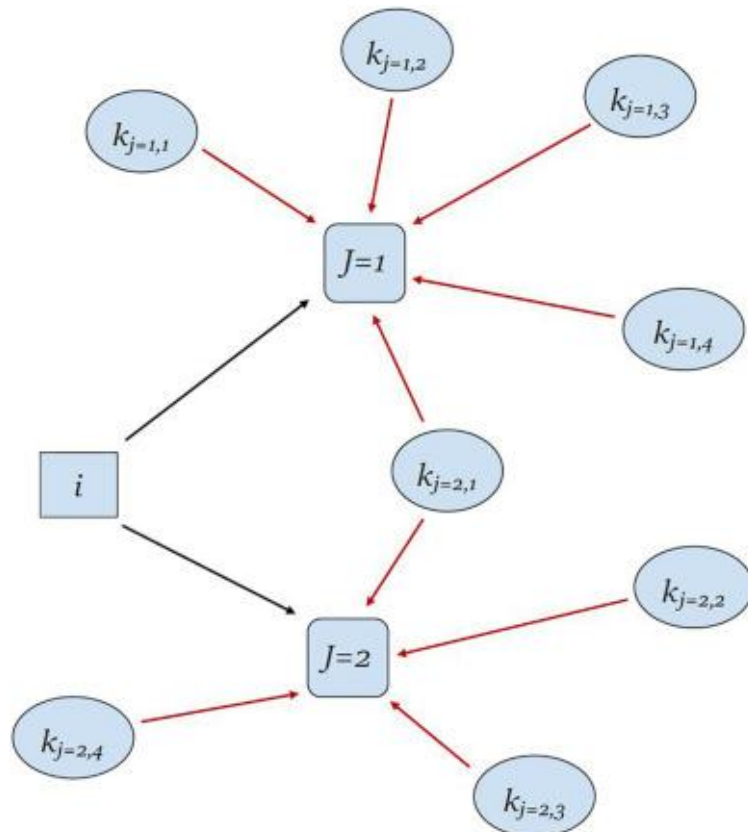


Figure 3. Illustration of the accessibility approach under competition by Kelobonye et al. [8]

This study adopts the competition-adjusted cumulative opportunity method proposed by Kelobonye et al. [8]. As illustrated in Figure 3, an origin i may reach multiple destinations $j=1,2,\dots,n$, while each destination is also reachable from other origins ($k1, k2, \dots$), each representing a competing demand node. Ignoring this competition tends to overestimate accessibility in dense inner areas where many people can reach the same facilities, and underestimate it in peripheral zones where fewer people compete for available opportunities [8].

The competition-adjusted cumulative opportunity measure is expressed as:

$$A_i = \sum_{j=1}^n \frac{cE_j}{\sum_{k=1}^n yP_k} \quad (2)$$

In this formulation, A_i represents the effective accessibility of origin zone i , representing the average number of opportunities available per potential user. The formula accounts for the total number of reachable destinations and the population competing for those destinations. The numerator measures the total number of opportunities available within a defined time threshold. Here:

E_j is the number of opportunities at destination j ,

c is a binary coefficient, equal to 1 if zone j is reachable from i within the time threshold, and 0 otherwise.

The denominator captures the total competing population. Specifically:

P_k denotes the population in zone k that can access the same destination zone j ,

y is a binary value indicating whether zone k is within the same time threshold from j .

The results express effective accessibility as opportunities per person (opps/person). For example, suppose origin zone i with 200 people can reach two job destinations within the 30-minute threshold, containing 300 jobs in total. Both destinations are also reachable by two competing zones with populations of 500 and 300 respectively. Since all reachable zones, including i itself, are treated as competitors, the total competing population is 1,000. The effective accessibility of zone i is therefore 0.3 opportunities per person, rather than the nominally accessible 300 opportunities. This method mitigates the bias toward dense inner areas and better captures the distributive equity of transport access. This study applied it to the assessment of four opportunity types in ISEMR: employment, education, healthcare, and retail.

3.3 Data Collection

The analysis draws on a combination of government and open-source datasets. All datasets were aligned to the Statistical Area Level 2 (SA2) spatial unit prior to analysis. Table 1 summarises the data used in this study.

Several data selection decisions warrant further explanation. For educational destinations, this study selected early childhood, primary, and secondary schools, while excluding tertiary institutions such as universities and colleges. Typically, trips to primary and secondary schools are regular and temporally concentrated in peak commuting periods. By contrast, university and colleges enrollments involve less predictable travel patterns that extend well beyond local catchments [8, 44]. This study primarily focus on local accessibility.

Furthermore, for the competing population (P_k), different age subsets were applied to reflect the realistic demand for each service type. The labour force population, comprising employed and unemployed persons aged 15 years and over, was used for employment. The school-age population aged 5 to 19 years was used for education. For healthcare and retail, the total resident population was applied, reflecting the universal relevance of these services across all demographic groups.

Table 1. Data sources

Data Type	Source	Description
Statistical Area Level 2 (SA2) boundaries	Australian Bureau of Statistics [49]	Digital boundary files defining SA2 spatial units under the Australian Statistical Geography Standard (ASGS). SA2 served as the primary unit of spatial analysis, with all datasets matched and aggregated to this scale.
General Transit Feed Specification (GTFS)	Department of Transport and Planning [50]	A schedule dataset covering all metropolitan trains, trams, and buses in Victoria. It includes stop locations, route structures, service frequencies, and scheduled travel times, and was used to construct the public transit component of the multi-modal transport network for travel time matrix computation.
Vicmap Transport - Road Line	Department of Transport and Planning [51]	A state-wide line feature dataset representing the Victorian road network. It was used to supplement the GTFS data in building the multi-modal network model, enabling the routing of pedestrian and road-based access segments.
2021 Census General Community Profile	Australian Bureau of Statistics [52]	Census Data pack provides resident population data by all age group at the SA2 level. Age-specific subsets were extracted to represent the competing demand population (Pk) for each service type in the accessibility model.
2021 Census Working Population Profile	Australian Bureau of Statistics [53]	Census data providing employment counts by place of work at the SA2 level. Employment counts were used to represent job opportunities (Ej). Industry-specific employment data were also used as proxies for service capacity in the healthcare and retail accessibility models.
VicMap Features of Interest (FOI)	Department of Transport and Planning [54]	A point dataset capturing the locations of key urban services across Victoria. Healthcare facilities and retail were extracted from this dataset to define destination points (Ej) for healthcare and retail accessibility calculation.
All schools Full Time Equivalent (FTE) Enrollments	Department of Education - Performance and Evaluation Division [55]	Enrolment figures for all Victorian schools based on schools census, used to represent the number of educational opportunities (Ej) at each school destination.
Socio-Economic Indexes for Areas (SEIFA)	Australian Bureau of Statistics [13]	Socio-economic index dataset comprising four composite indices. The Index of Relative Socio-Economic Disadvantage (IRSD) was selected in this study, and was used in the social equity analysis to examine the correspondence between accessibility outcomes and social disadvantage.

3.4 Data Processing

3.4.1 Departure Time

PT accessibility varies throughout the day as service frequencies and waiting times change across different periods [56]. Departure times were therefore selected to reflect the typical timing of travel associated with each opportunity type. For employment and education, travel times were calculated using weekday departures at 8:00 AM. For healthcare and retail, departures were set at 1:00 p.m. during the inter-peak period. Accessibility was calculated using GTFS schedules for 15 October 2025, a regular weekday chosen to represent typical operating conditions.

3.4.2 Travel Time Thresholds

There is no unified standard for setting thresholds in cumulative opportunity method for different types of opportunities (as discussed in Section 2.2.2). In practice, researchers usually make contextual adjustments based on travel characteristics and local policy goals [8]. For employment and education, a 30-minute one-way threshold was applied in this study. This is consistent with research on commuting time stability and Australian planning policy [57, 58]. In contrast, healthcare and retail

are more aligned with localized travel patterns. The time threshold is set at 20 minutes under Melbourne "20-minute neighbourhoods" policy [59]. Table 2 summarises the thresholds applied for each service type.

Table 2. Departure times and travel time thresholds by service type

Service type	Departure time	Travel time threshold
Employment	8:00 AM	30 minutes
Education	8:00 AM	30 minutes
Healthcare	1:00 PM	20 minutes
Retail	1:00 PM	20 minutes
<i>Note.</i> The data is based on scheduled services for 15 October 2025.		

3.4.3 Multimodal Network Construction And Origin-Destination (OD) Matrix

All spatial datasets were processed in ArcGIS Pro, with coordinate reference systems unified to GDA2020. The GTFS schedule data and the road network were used to construct a multi-modal transport network. The population-weighted centroid of each SA2 served as the origins in the OD matrix, as this approach better reflects actual residential distribution within a zone than the geometric centroid [60]. Travel time matrices were then generated from all SA2 centroids to each of the four destination types across the Melbourne metropolitan region. This metropolitan-scale framing is necessary because PT connectivity does not respect administrative boundaries, and the competition-adjusted model requires a complete count of all populations able to reach each destination within the threshold. The resulting accessibility measures were then analysed for the 34 SA2s located within the ISEMR study area.

3.5 Equity Assessment

3.5.1 Spatial Equity Assessment

To answer sub-question 1, descriptive statistics (mean, standard deviation, and coefficient of variation) were calculated for each service type to summarise accessibility levels and assess variation across the 34 SA2 units in ISEMR. To identify areas experiencing disadvantage across multiple service types, the four accessibility indices were normalised using min-max normalisation and combined into a Composite Accessibility Index (CAI). The resulting CAI was classified into low, medium and high accessibility tertiles. Given the relatively small number of SA2 units ($n = 34$), tertiles provided a simple and interpretable classification of accessibility differences.

3.5.2 Social Equity Analysis

To examine the relationship between accessibility and socio-economic disadvantage, the Index of Relative Socio-economic Disadvantage (IRSD) was selected as the socio-economic indicator. Of the four SEIFA indices, IRSD captures dimensions most relevant to transport disadvantage, including low income, unemployment and low educational attainment [13]. However, IRSD scores are reported as national rankings, thus provide limited differentiation within Melbourne's relatively advantaged inner metropolitan areas [61]. To improve local comparability, IRSD values were reclassified into tertiles representing relatively high, medium and low levels of disadvantage within ISEMR.

CAI and IRSD tertiles were combined in a 3×3 classification matrix representing all possible combinations of accessibility and disadvantage across the 34 SA2 units. The matrix distinguishes five categories of accessibility-disadvantage outcomes. Four represent clearly interpretable equity conditions: double disadvantage (low accessibility and high disadvantage), spatial disadvantage only (low accessibility and low disadvantage), social disadvantage only (high accessibility and high disadvantage), and double advantage (high accessibility and low disadvantage). The remaining combinations were grouped as intermediate categories, representing mixed accessibility and disadvantage profiles that do not indicate a clear equity condition. Also, it should be noted that the

tertile categories represent relative socio-economic standing within ISEMR and should not be interpreted as absolute levels of disadvantage across metropolitan Melbourne.

4. Results

4.1 Supply-Demand Overview

Table 3 presents the supply-demand ratios for the four service types across the Melbourne metropolitan region. The ratios of employment (0.79) and education (0.92) are naturally close to 1. For the reason that they share an inherent one-to-one correspondence: a job position always corresponds to one employee, and a school place corresponds to one student. For healthcare and retail accessibility, supply was represented by the number of healthcare workers and retail employees, respectively. Because each provider can serve multiple users, supply and demand are not directly comparable in their original form. Consistent with Kelobonye et al. [8], both service types were rescaled to produce a calibrated ratio of approximately 1. This rescaling does not alter the spatial distribution of opportunities across zones. It ensures that all four service types can be expressed on the same opportunities per person (opps/person) basis and interpreted consistently in the subsequent accessibility analysis.

Table 3. Supply-demand ratios for the four service types in Melbourne metropolitan region

Service	Supply	Demand	Ratio
Employment	2,376,617	3,011,509	0.79
Education	806,596	875,664	0.92
Healthcare	329,874 (x 14.9)	4917,633	0.067 (1)
Retail	229,046 (x 21.47)	4917,633	0.046 (1)

Note. Values in parentheses in the Supply column indicate the rescaling factor applied; values in parentheses in the Ratio column indicate the supply-demand ratio after rescaling. Rescaling factor = demand/supply. Healthcare: $4917,633/329,874 = 14.9$; Retail: $4917,633/229,046 = 21.47$.

4.2 Spatial Equity

4.2.1 Effective Accessibility And Descriptive Statistics of Four Service Types

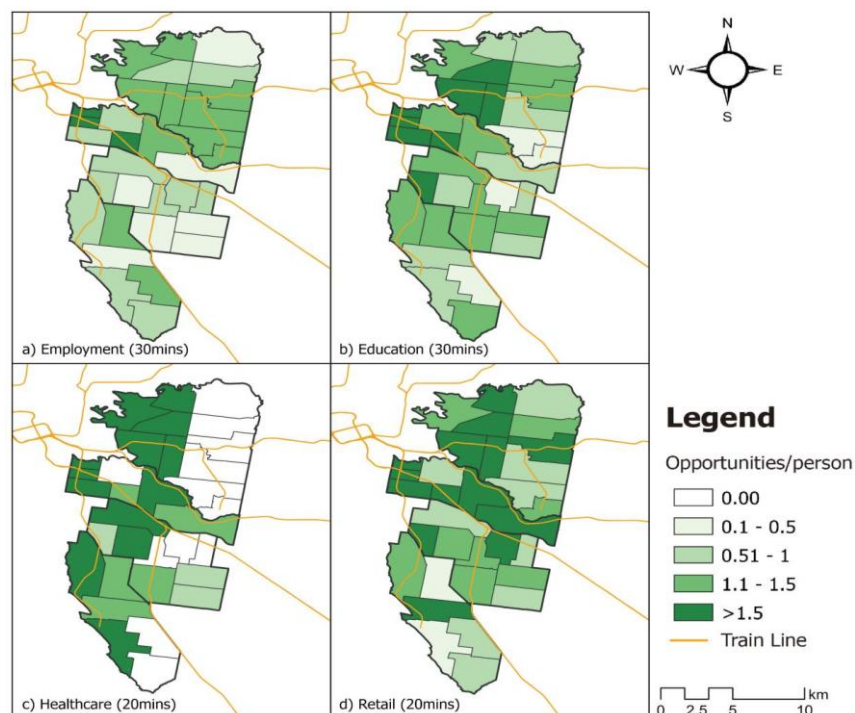


Figure 4. Competition-adjusted PT accessibility to (a) employment, (b) education, (c) healthcare and (d) shopping within ISEMR

Table 4. Descriptive statistics of effective accessibility for four service types

Service	Mean (opps/person)	Standard Deviation	Coefficient of Variation
Employment	0.78	0.39	0.5
Education	1.09	0.71	0.65
Healthcare	1.35	1.4	1.04
Retail	1.66	1.09	0.66

Figure 4 presents the competition-adjusted PT accessibility to employment, education, healthcare, and retail within ISEMR. An accessibility value of 1 represents the theoretical equilibrium at which reachable opportunities match the competing population. Values below 1 indicate that residents face meaningful competition for accessible opportunities, the lower the value, the more severely access is compressed by demand. Zero values indicate the complete absence of reachable opportunities within the specified travel time threshold. Table 4 summarises the mean, SD, and CV for each service type.

Employment accessibility (Figure 4a) displays a predominantly low-to-moderate spatial pattern. The majority of SA2s fall within the 0.1-1 opps/person range. Higher values (1.1-1.5 and >1.5) concentrated in the western parts of Stonnington where multiple train lines converge. No SA2 records zero employment accessibility meaning that all residents can reach at least some job opportunities within the 30-minute threshold. Nevertheless, the mean of 0.78 opps/person is the only value below equilibrium across all four service types. It means that on average, residents face more competition than available opportunities can accommodate. The CV for employment services, however, was the lowest among the four service types (0.50), indicating that accessibility inadequacy is relatively evenly distributed within the ISEMR region.

For education (Figure 4b), higher-accessibility SA2s are concentrated in the western parts of Boroondara and Stonnington, and lower-accessibility persist in the eastern parts of both areas and across Glen Eira. The mean of 1.09 opps/person sits just above equilibrium, with a moderate CV of 0.65. Although the regional average remains slightly above equilibrium, several eastern SA2s recorded below-equilibrium accessibility indicate that competition pressures are unevenly distributed across the region.

Healthcare accessibility (Figure 4c) presents the most spatially polarised pattern among the four service types. Hospitals and clinics are highly concentrated in the western part of ISEMR, while large areas in the east have zero accessibility, especially Boroondara and Glen Eira. Although the mean reaches 1.35 opps/person, healthcare records the highest SD (1.40) and CV (1.04), suggesting that regional averages mask considerable local variation.

Retail records the highest overall accessibility (Figure 4d), with the mean of 1.66 opps/person and many SA2s in the north and central areas exceeding 1.5 opps/person. Nevertheless, several Bayside SA2s record accessibility values between 0.1 and 0.5 opps/person, substantially lower than the regional average.

4.2.2 Multi-Service Accessibility Inequity

Figure 5 shows the spatial distribution of the CAI across the 34 SA2 units in ISEMR. Overall accessibility exhibits a clear west-east gradient.

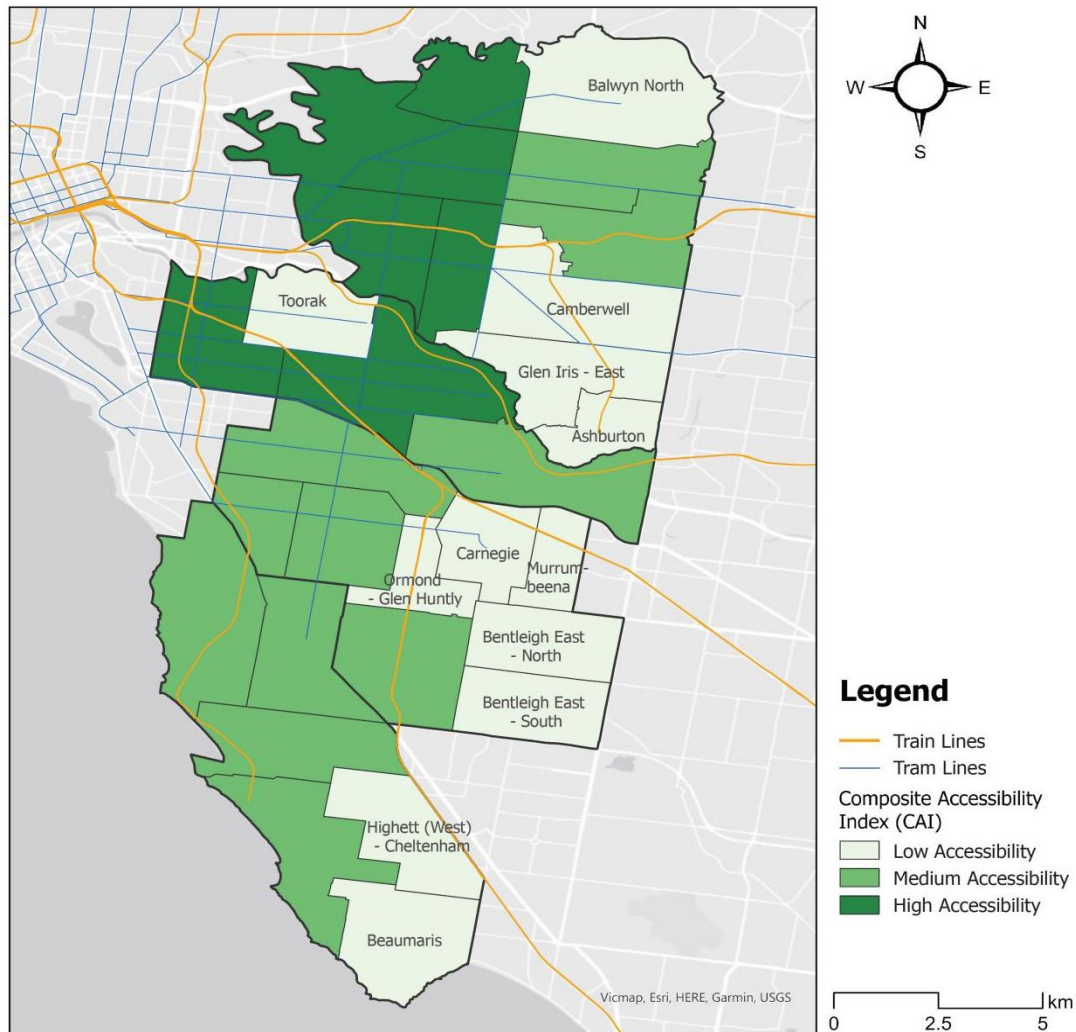


Figure 5. Composite Accessibility Index (CAI) within ISEMR

The highest CAI values are concentrated in the north-western part of the region, particularly within Stonnington and western Boroondara, where tram and rail corridors overlap. Accessibility declines progressively towards the east and south-east, with a broad band of medium-accessibility SA2s forming a transition between these areas. The lowest CAI values are concentrated in eastern Boroondara, Glen Eira and parts of Bayside. Accessibility to multiple opportunity types in these areas is constrained by limited proximity to major tram and rail services. Together, these findings show that multi-service accessibility disadvantage has spatially structured and concentrated in areas beyond Melbourne's principal PT corridors.

4.3 Social Equity

4.3.1 Socio-Economic Profile of ISEMR

Figure 6 presents the reclassified IRSD distribution across ISEMR. Areas of relatively low disadvantage are concentrated in Boroondara, whereas higher levels of disadvantage are more common in Glen Eira and several SA2s in Bayside and western Stonnington. Unlike the CAI, socio-economic disadvantage does not display a clear metropolitan gradient, instead occurring in a series of localised clusters across the region. Several of these higher-disadvantage areas coincide spatially with the low-accessibility locations identified in the previous section. They suggest a possible overlap between social and spatial disadvantage.

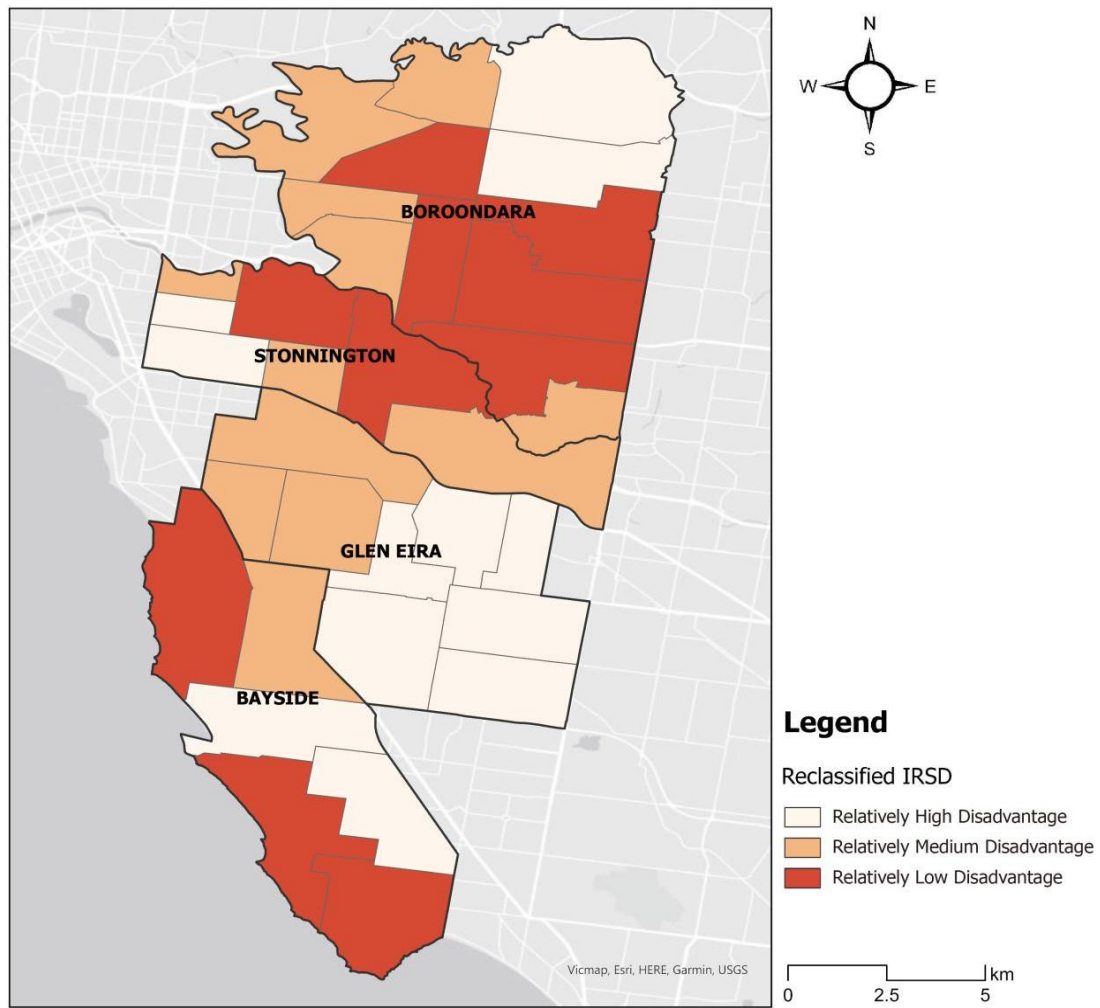


Figure 6. Reclassified IRSD within ISEMR

4.3.2 Cross-classification of CAI and IRSD

Table 5. Classification matrix by accessibility and socio-economic disadvantage

Reclassified IRSD / CAI	Low Accessibility	Medium Accessibility	High Accessibility	Total
High Disadvantage	7	3	2	12
Medium Disadvantage	1	4	7	12
Low Disadvantage	4	3	3	10
Total	12	10	12	34

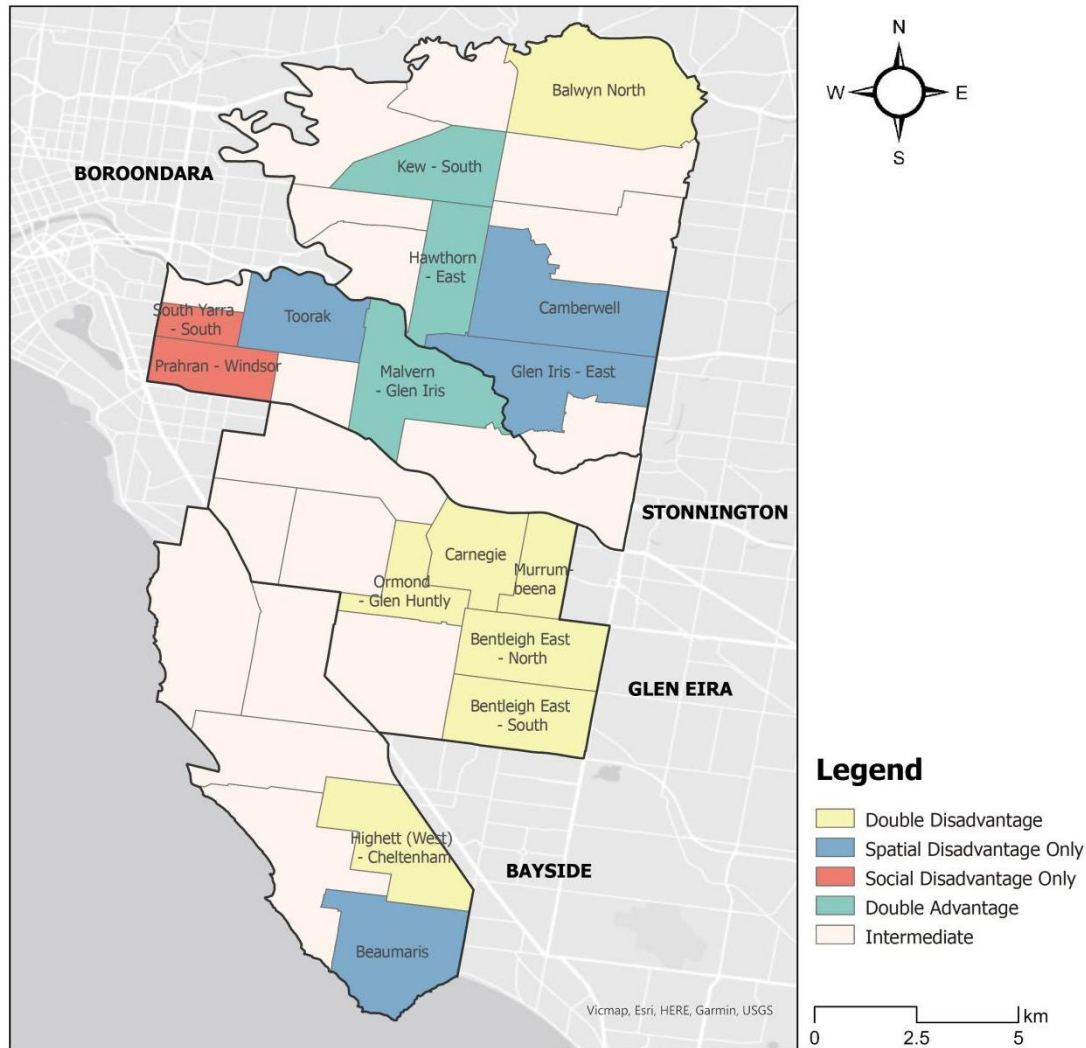


Figure 7. Spatial distribution of five categories across ISEMR

Table 5 shows the cross-classification of CAI and IRSD of 34 SA2 units, and the spatial distribution shown in Figure 7. There is a clear concentration of double disadvantage in the south-eastern part of ISEMR. Seven SA2s combine low accessibility with high socio-economic disadvantage, including Ormond-Glen Huntly, Carnegie, Murrumbeena, Bentleigh East North, Bentleigh East South, Highett West-Cheltenham and Balwyn North. With the exception of Balwyn North, these areas form a contiguous cluster across Glen Eira and Bayside. They indicate a spatial overlap between limited PT accessibility and relatively high socio-economic need.

Not all accessibility outcomes correspond closely with socio-economic conditions. Four SA2s record low accessibility despite relatively low levels of disadvantage, demonstrating that favourable socio-economic circumstances do not necessarily coincide with strong PT access. In contrast, only two SA2s combine high accessibility with high disadvantage. Both are located along major PT corridors on the western edge of ISEMR. That means accessibility advantages may partly compensate for underlying socio-economic vulnerability. Areas of double advantage are concentrated within the central transport corridor, where accessibility and socio-economic advantage coincide.

The remaining 18 SA2s fall within intermediate combinations and are distributed throughout the region. Owing to the diversity of accessibility and disadvantage profiles represented within this group, no consistent spatial pattern is evident.

Overall, the strongest correspondence between accessibility and disadvantage occurs in the south-eastern part of ISEMR, where low accessibility and high socio-economic disadvantage coincide. This pattern suggests that transport disadvantage within the region is concentrated in a relatively small number of locations rather than evenly distributed across the study area.

5. Discussion

5.1 Competition and Effective Accessibility

The standard cumulative opportunity measure assumes that all reachable opportunities are equally available to all users [8]. This assumption is less convincing in high-density urban areas, where large populations compete for a limited number of opportunities. In these settings, the presence of nearby opportunities does not necessarily translate into effective access.

The employment results confirm the argument for competition. Its accessibility records the only mean below equilibrium (0.78 opps/person) among the four service types. Given the relatively extensive PT network within ISEMR, this finding suggests that competition for jobs remains substantial. Improved connectivity increases the number of reachable employment opportunities, but it also increases the number of workers able to compete for those opportunities. As a result, accessibility may remain constrained even in areas with comparatively strong transport provision. The competition-adjusted measure makes this constraint visible. Under a standard cumulative opportunity measure, many of these locations would simply appear to have access to a large number of jobs. By incorporating competing demand, the measure provides a more realistic representation of effective accessibility and offers a stronger basis for assessing transport equity in high-density urban environments.

5.2 Spatial Equity: Network Structure And Service Geography

Much of the Melbourne transport equity literature has focused on the contrast between well-served inner suburbs and disadvantaged outer suburban areas. Yet the findings suggest that accessibility is unevenly distributed within ISEMR despite its generally favourable inner-metropolitan location.

The observed pattern largely reflects the structure of Melbourne's PT network. Higher accessibility in the northern and western parts of ISEMR is close to the major rail and tram corridors, which radiate from the CBD. The eastern and southern edges of ISEMR sit further from these routes and consistently record weaker outcomes. This is not a reflection of PT absence, but rather of how radial corridor-based network design distributes connectivity unevenly across space. This a structural feature of Melbourne's PT system that has been identified as a persistent source of intra-urban inequity [62, 63]. Within a generally well-served inner region, this corridor pattern still produces systematic disadvantage for areas that fall between major routes.

The four service types, however, do not respond uniformly to this structural disadvantage, because they operate through different spatial and functional logics. Employment and retail destinations are relatively dispersed across ISEMR, meaning that even residents in areas with weaker PT connectivity can reach some opportunities within their respective thresholds. As a result, both service types display moderate spatial gradients rather than sharp polarisation. Healthcare, by contrast, exhibits the most acute spatial polarisation of all four service types, with a substantial number of SA2s in Boroondara and Glen Eira recording zero accessibility (see Figure 4c). The result produced by the joint effect of spatially concentrated facilities in the north-western corridor and a comparatively short 20-minute threshold. This combination makes healthcare accessibility the most sensitive to locational disadvantage among the four service types.

Taken together, spatial inequity within ISEMR is not random but structurally produced. It reflects the geometry of Melbourne's radial PT network relative to the spatial distribution of urban services. Alignment between network corridors and facility locations produces strong effective accessibility, while spatial divergence between the two generates access deficits even within an inner metropolitan region.

5.3 Social Equity: Structured Correspondence Between Accessibility And Disadvantage

Despite ISEMR's broadly advantaged profile in national socioeconomic rankings, meaningful differentiation in relative disadvantage exists within the region when IRSD scores are assessed relative to the intra-regional distribution (see Figure 6). The reclassified IRSD reveals a gradient from

relatively lower disadvantage in the north and west to relatively higher disadvantage in the south and east. This pattern broadly resembles the suburbanisation of disadvantage observed in Australian cities, although it is evident here within a much smaller inner-metropolitan region [64]. It therefore suggests that socio-economic differentiation remains substantial despite the area's generally advantaged profile.

The cross-classification results reveal a systematic but incomplete overlap between spatial accessibility and socioeconomic disadvantage. Seven of the twelve high-disadvantage SA2 units simultaneously record low multi-service accessibility, constituting a double-disadvantage cluster concentrated in the south-east of ISEMR (see Figure 7). The overlap suggests that residents facing greater socio-economic constraints are also more likely to experience limited access to urban opportunities. The reinforcing relationship between transport constraints and social exclusion is well-established in the Australian context [3, 65]. The findings indicate that this relationship is also evident within an otherwise well-served inner-metropolitan region.

Equally important, the cross-classification also reveals different patterns. The spatial disadvantage only category shows that relatively favourable socio-economic conditions do not guarantee strong PT accessibility. Residents in these areas may currently compensate for weak PT connectivity through private means such as car ownership. Nevertheless, this does not make the spatial deficit acceptable. These areas remain structurally vulnerable to future conditions -including ageing populations, declining incomes, or rising transport costs -that could rapidly convert latent spatial disadvantage into material transport hardship [11]. Spatial inequity without present social disadvantage therefore warrants proactive planning attention rather than complacency.

Moreover, the social disadvantage only category indicates that relatively strong PT accessibility can coexist with higher socio-economic disadvantage. Both units in this category are located along high-frequency PT corridors. This suggests that strong PT accessibility may help reduce some of the mobility constraints commonly associated with socio-economic disadvantage [65]. Nevertheless, accessibility advantages should not be interpreted as evidence of broader social advantage. Transport may improve access to opportunities, but it cannot address the underlying causes of socio-economic disadvantage [5].

Rather than showing a complete overlap between accessibility and disadvantage, the results reveal a more complex relationship. Some disadvantaged areas experience poor accessibility, while others benefit from relatively strong access to opportunities. Likewise, low accessibility is not confined to disadvantaged communities. Each dimension highlights forms of disadvantage that cannot be identified through the other alone. As a result, spatial and social conditions should be considered together when identifying priorities for intervention.

6. Planning Implications, Limitations and Future Research

6.1 Implications for Accessibility And Equity Analysis

Two broader implications emerge for transport equity research and planning practice. First, accessibility measures do more than describe transport conditions. They shape how inequality is recognised and how planning priorities are defined [66, 67]. While cumulative opportunity measures remain useful because of their simplicity and policy legibility, the case study of ISEMR shows that raw counts of reachable opportunities are insufficient in high-demand urban contexts.

Recent studies have argued that accessibility measures should better account for competition and capacity constraints [8, 37]. In the context of ISEMR, incorporating competition reveals accessibility deficits masked by aggregate-level assessment. Therefore, the practical implication of competition-adjusted accessibility lies in its potential as an equity diagnostic tool, helping planners identify internal disparities in such high-supply urban areas.

Second, the study demonstrates the value of integrating spatial and social dimensions of equity within a single assessment framework. The cross-classification of CAI and IRSD was used to distinguish different equity situations: double disadvantage, spatial disadvantage only, social disadvantage only, and double advantage. Each category implies different planning responses. For

example, areas with double disadvantage require the strongest equity-oriented interventions, while areas with only spatial disadvantage may require preventative planning given their future vulnerability to demographic ageing or declining car access.

Transport equity practitioners are increasingly seeking accessibility analyses that can guide future investment decisions, rather than merely evaluate existing conditions [67]. This requires accessibility analysis to function not only as a descriptive mapping tool, but more importantly, as a prioritization tool for planning resource allocation. The cross-classification framework developed in this study directly supports this aim, translating complex spatial and social outcomes into policy-relevant categories.

6.2 Implications for Transport Investment And Planning in ISEMR

The accessibility inequalities identified within ISEMR suggest that future transport investment should prioritise improving network connectivity. Melbourne's radial PT corridors facilitate travel between the suburbs and the CBD, while cross-suburban connections are relatively indirect and infrequent [62]. Even in areas close to these corridors, the meandering route structures are needed to meet the excessively large range of demand. The west-to-east accessibility gradient observed in this study confirms this pattern. Current policy development therefore should prioritise cross-corridor routes connecting activity centres in the eastern part of ISEMR, while simultaneously increasing the frequency of existing circular transit services. Such measures would be particularly beneficial to the double-disadvantaged southeastern part of the region.

The findings also indicate that accessibility planning should be more closely integrated with land use and service location decisions. The spatial pattern of healthcare accessibility differs significantly from that of employment, education, and retail, reflecting a concentration of healthcare facilities in relatively few locations. Consequently, addressing the inadequacy of healthcare accessibility in Boroondara and Glen Eira cannot rely solely on transport improvements. A more effective strategy would combine targeted PT enhancements with the decentralisation of community health facilities and primary healthcare services toward currently under-served areas. This approach can both reduce travel demand and address the spatial mismatch between service delivery and local needs.

6.3 Limitation and Future Research

The competition-adjusted cumulative opportunity measure adopted in this study remains a location-based accessibility approach and therefore does not account for individual travel behaviour or destination preferences. In reality, access to opportunities is also shaped by a range of behavioural and institutional factors beyond spatial reachability. For example, employment accessibility is influenced by the qualifications of job seekers and the preferences of employers, while access to educational opportunities may be constrained by school admission policies or family's choice [8]. Similar considerations apply to healthcare and retail choices, where individual preferences and perceived service quality often affect destination selection. Such limitations are common to most location-based accessibility frameworks and reflect an inherent trade-off between behavioural realism and analytical tractability [7, 35]. Despite this limitation, the approach remains useful for examining broad patterns of accessibility inequality. Future work could combine competition-adjusted accessibility measures with travel survey or behavioural data to explore how opportunity choice varies between individuals.

The accessibility analysis relies on scheduled GTFS data, but they cannot reflect factors such as service unreliability, delays, missed transfers, vehicle congestion, or daily operational fluctuations [68, 69]. The results therefore represent accessibility under scheduled operating conditions rather than actual travel experiences. Recent studies using GTFS-realtime data show that service delays and travel time uncertainty can affect accessibility outcomes [70]. These effects may be particularly important in high-demand PT systems, where congestion and operational disruptions are more common. Nevertheless, scheduled GTFS data remain widely used in accessibility research because

they provide a consistent representation of network structure and planned service levels across large metropolitan areas.

IRSD is an area-based indicator, it captures broad patterns of disadvantage within the population rather than the circumstances of specific individuals or social groups. Previous research has shown that older adults, people with disabilities, recent immigrants and other population groups may face transport barriers that are not fully reflected in area-level socio-economic indicators [5; 66]. In this study, to better distinguish socio-economic variation within ISEMR, IRSD scores were reclassified into tertiles. This approach helps identify relative differences within a region where most areas fall within Melbourne's more advantaged socio-economic categories. Nevertheless, disadvantaged individuals may still live in relatively advantaged areas, and vice versa. Future research could complement this spatial perspective with individual-level survey data or population-specific analysis. This would provide a clearer understanding of how accessibility inequalities are experienced by different groups within the same local context.

7. Conclusion

This research set out to examine how PT accessibility is distributed within ISEMR once opportunity competition is taken into account, and whether patterns of accessibility correspond to socio-economic disadvantage. The results show that accessibility within ISEMR is far from uniformly high despite the region's extensive PT network. A clear west-east gradient is evident across four types of service, with accessibility concentrated along Melbourne's major rail and tram corridors. Healthcare exhibits the strongest spatial inequality, including large areas of zero accessibility. Employment is the only type of opportunity that is below the average number of opportunities per person.

The relationship between spatial accessibility and socio-economic disadvantage is systematic but incomplete. A cluster of double disadvantage emerges in the south-eastern part of ISEMR, where low multi-service accessibility coincides with relatively high socio-economic disadvantage. At the same time, several areas display only spatial disadvantage or only social disadvantage. This suggests that accessibility inequality and socio-economic disadvantage do not map onto each other perfectly. Assessing one without the other risks overlooking important forms of transport inequity.

The study also demonstrates the value of incorporating competition into accessibility assessment. In high-demand urban environments, the number of reachable opportunities alone may provide a misleading picture of accessibility because those opportunities are simultaneously available to many competing users. The employment results illustrate this clearly: despite strong PT provision, competition-adjusted accessibility remains below equilibrium across much of the region.

More broadly, the findings challenge the tendency within Australian transport equity research to associate disadvantage primarily with outer-suburban locations. While accessibility deficits in peripheral areas remain an important concern, this study demonstrates that meaningful inequalities can also emerge within comparatively advantaged inner metropolitan regions. Such environments are characterised by dense concentrations of both opportunities and population, meaning that competition for access may become an important source of inequality even where PT provision is extensive. These findings suggest that transport equity should be understood not only as a metropolitan-scale issue but also as an intra-metropolitan one.

By integrating competition-adjusted accessibility with socio-economic analysis, this study provides a transferable framework for identifying forms of disadvantage that may otherwise remain hidden within apparently well-served urban areas. The framework can assist planners in distinguishing between different equity conditions and prioritising interventions according to local needs. In doing so, it supports a more targeted and evidence-based approach to equity-oriented planning.

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