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Assessing interaction quality between multimodal transit interchanges: A Melbourne case study

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1 Introduction

Multimodal integration is widely recognised as a cornerstone of sustainable and efficient urban mobility systems (Tanwar & Agarwal, 2025; Chowdhury et al., 2018). While much research has examined the design and quality of individual interchanges, far less attention has been paid to the quality of the connections between them (Alessandretti et al., 2023). Yet these connecting routes, such as pedestrian pathways, cycling lanes, and emerging micromobility options, are essential to enable transit systems to function as coherent multimodal networks (Rahaman et al., 2016).

Existing frameworks, such as the Node-Place (Bertolini, 1996) and the Node-Place-Experience model (Groenendijk et al., 2018), focus on interchange nodes rather than the infrastructure that links them. Studies highlight relevant quality factors including accessibility (Vale, 2015), information and security (Lois et al., 2018), and comfort (Pshinko et al., 2022), with some attention to user groups such as passengers with reduced mobility (Solecka et al., 2020). More comprehensive approaches, such as those by Diana et al. (2016), capture quality across multimodal travel chains, but typically exclude micromobility, which is becoming a key element of sustainable urban mobility. Similarly, most studies evaluate individual modes (e.g., walking: Talavera-Garcia & Soria-Lara, 2015; cycling: Calvey et al., 2015; Local Public Transport (LPT): Barabino, 2018; bike-sharing: Hsu, 2018; micromobility: Aguilera-Garcia et al., 2020; Hamerska et al., 2022) rather than their combined functioning in multimodal contexts (Keijer & Rietveld, 2000; Venter, 2020; Kosmidis & Müller-Eie, 2023).

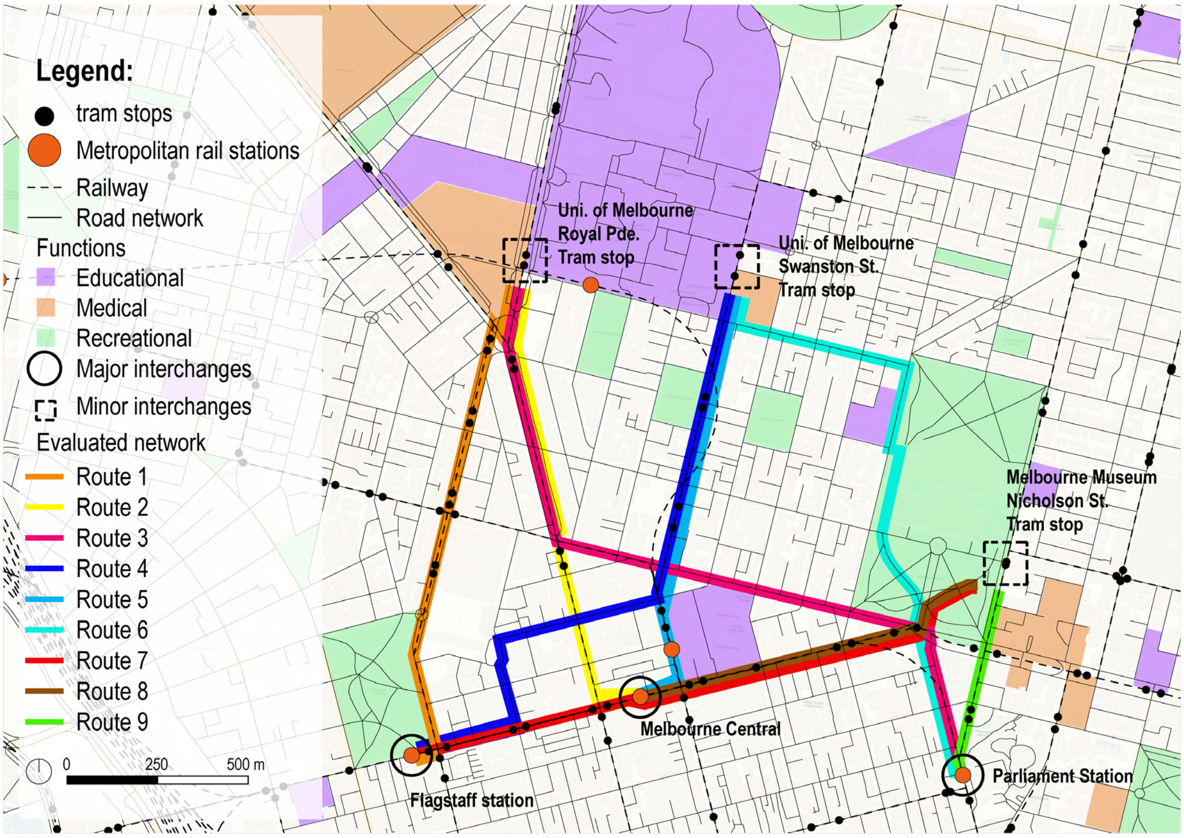
Another limitation lies in the methodologies employed. Many assessments are based either on agency-driven objective measures (Transportation Research Board, 2003) or on subjective perceptions gathered through Customer Satisfaction Surveys (Eboli & Mazzulla, 2011). Recent work has suggested subjective and objective approaches (Barabino & Di Francesco, 2016). However, comprehensive, replicable tools that focus on the user perspective by objective methods and are applicable across multiple sustainable transport modes remain scarce.

This study addresses these gaps by proposing a new measure of interaction quality between multimodal interchanges, centred on the user perspective but operationalised through objective, easily measurable indicators. The framework covers eight key criteria - accessibility, availability, comfort, customer care, environmental impact, information, safety and security, and time - and is applied to a case study in Melbourne, Australia. By assessing nine routes linking major and minor interchanges north of the Central Business District, the research provides both a methodological contribution and practical insights for planners and policymakers seeking to enhance the effectiveness and sustainability of multimodal urban mobility systems.

2 Methodology

The study develops and applies a new measure of interaction quality between multimodal interchanges in Melbourne, Australia. The case study area is the northern Central Business District, a densely populated and mixed-use district comprising hospitals, universities, schools, and residential areas that generate substantial daily travel demand (Australian Bureau of Statistics, 2016). Three metropolitan rail stations (Flagstaff, Melbourne Central, and Parliament) were selected as major interchanges, and three nearby tram stops ("University of Melbourne/Royal Parade", "Melbourne University/Swanston Street", and "Melbourne Museum/Nicholson") were identified as minor interchanges. These nodes were connected through nine routes (R1–R9), mapped using GIS (Figure 1). Routes represent strategic links in the local network rather than specific demand patterns, and the analysis focuses on the physical and functional quality of these connections across multiple sustainable modes: walking, cycling, e-micromobility, and local public transport (LPT).

Figure 1: Route framing connecting major interchanges with minor interchanges in the area north of Melbourne CBD. Source: personal elaboration.



The proposed quality measure was designed around the eight dimensions of service quality defined by the European Standard EN 13816 (2002): accessibility, availability, comfort, customer care, environmental impact, information, safety and security, and time.

These dimensions were operationalized into first and second-level parameters and, ultimately, into a set of forty-three indicators that capture both infrastructural and service aspects of multimodal mobility (Table 1). Indicators include, for example, the presence of ramps at public transport stops, the continuity of pedestrian and cycling facilities, the provision of shared micromobility services, levels of cleanliness and amenities, access to customer service, the extent of green areas, the presence of signage and tactile information, lighting conditions, traffic volumes, and travel or waiting times.

On the basis of the research literature, the measure considers the quality criteria (C) of Accessibility, Availability, Comfort, Customer care, Environmental impact, Information, Safety and Security, and Time. Each criterion C_i is divided into first- and second-level parameters (P_{ij}). These parameters are the elements that contribute to the score for each criterion and are further subdivided into indicators (I_{ijk}) that have a score and relative significance weighting (Table 1). The overall quality score for a given route (S_{route}) is the sum of the weighted scores for all indicators across all criteria and parameters.

Let's define the following variables:

- R be the set of route and $r \in R$ a generic route;
- I be the set of criteria (e.g., Accessibility, Comfort, etc.) and $i \in I$ a generic criterion;
- J (i) be the set of parameters for criterion $i \in I$, and $j \in J(i)$ a single parameter;
- K (i,j) be the set of indicators for criterion $i \in I$, parameter $j \in J(i)$ and $k \in K(i,j)$ a single indicator.
- S_{ijk} be the score of indicator $k \in K(i,j)$ related to criterion $i \in I$ and parameter j $\in J$;
- W_{ijk} be the weight of indicator $k \in K(i,j)$ related to criterion $i \in I$ and parameter $j \in J$.

The total score for each route (i.e, S_r) is computed as follows:

$$S_r = \sum_{i \in I} \sum_{j \in J(i)} \sum_{k \in K(i,j)} S_{ijk} \times W_{ijk} \qquad \forall\, r \in R \qquad [1]$$

The selection of indicators followed three principles: they had to be straightforward to measure, rely on data that are either publicly available or quickly obtainable, and remain feasible to collect in the field when desk-based information was lacking. Following this approach, approximately 22% of the required data were sourced from official open datasets (e.g., governmental open data portals, GIS-based resources, mobility service applications), while the remaining 78% were collected through direct field observations. Fieldwork was conducted in February and March 2025, during weekday peak hours (7:00–10:00 a.m. and 5:00–8:00 p.m.), with additional evening inspections to assess safety-related aspects, including lighting.

The weighting of the parameters is based on the authors' subjective views of the item's importance but this is informed by our review of the research literature. Several indicators are measured through the use of open data and provided by official sources, and on-site observation. Some required the use of the GIS tool for data extrapolation, such as the calculation of square meters of green areas. The next section provides a description of the measurement scale for each indicator.

Table 1: Quality criteria, parameters and indicators, classified based on the score of criteria (min-max).

Criteria	Parameters – level I	Parameters – level II	Indicators	Max Score
Customer care	Assistance Commitment	Customer orientation Innovation & initiatives	**2**	**55**
Environmental impact	Pollution & health	Natural resources	**2**	**60**
Time	Length of the trip	At O/b and a/D points	**5**	**85**
Accessibility	Internal interface	Entrance/exits	**3**	**105**
Safety & Security	Freedom from accident Freedom from crime	Traffic flow Lighting	**4**	**125**

Criteria	Parameters – level I	Parameters – level II	Indicators	Max Score
Comfort	Ambient conditions Complementary facilities	Cleanliness Amenities	**15**	**160**
Information	General information	About accessibility	**5**	**165**
Availability	Network	Area covered	**7**	**245**
Total			**43**	**1.000**

Each route was assessed against the full set of indicators. Scores were attributed according to predefined scales and subsequently aggregated through a weighted multi-criteria approach. The weighting reflected the relative importance of each criterion, drawing on insights from the literature and the authors' expertise. The resulting overall quality score for each route provides a comparative measure of the design quality of the multimodal links between major and minor interchanges.

3 Main findings

The analysis of nine routes in Melbourne reveals significant variation in interaction quality. Route 4 achieved the highest score, while Routes 1 and 3 performed worst. Across all routes, the Information criterion consistently reached maximum values, reflecting strong signage and accessibility features.

By contrast, Availability never reached its maximum because of the absence of scooter-sharing services, and interruptions in cycling infrastructure particularly affected Routes 1–3. Comfort was mixed: while Routes 4 and 6 were relatively clean, others were penalised by litter, graffiti and limited amenities such as covered bike racks or drinking water facilities.

Environmental impact scored medium–high overall, supported by the presence of public parks, though Route 3 lacked green areas entirely. Safety and security were undermined by consistently high motor vehicle flows, highlighting the need for policies to discourage car use. Customer care was limited everywhere by the reliance on virtual rather than physical services.

Regarding Time, cycling proved the most efficient mode across routes, while walking was only competitive on a few segments (R5, R8, R9). LPT performance varied: good in R5 and R9 but limited by waiting times exceeding five minutes in R6 and R7.

Overall, the findings highlight priority areas for intervention: introducing scooter-sharing, strengthening cycling continuity, improving infrastructure maintenance, and enhancing service frequency. These actions would help close critical gaps in multimodal connectivity and improve the user experience.

4 Conclusion

This study proposes a new indicator-based measure for assessing the quality of interactions between multimodal interchanges, encompassing walking, cycling, e-micromobility, and local public transport. The framework simplifies the complex concept of "quality" into objective and easily collected indicators, offering a practical tool to support sustainable mobility planning and policy (Joumard et al., 2011). By highlighting both strengths and gaps in existing networks, it provides clear guidance for interventions to improve multimodal connectivity.

The approach is replicable, quick to apply, and particularly valuable for preliminary assessments of route quality and design alternatives. Nonetheless, future work should integrate user perceptions with survey forms to be submitted in the field to better complement objective measures, refine indicator weightings using demand data and behavioural preferences, and consider economic valuation of quality attributes (e.g. Currie, 2005; Douglas & Wallis, 2013). These enhancements would further strengthen the tool's robustness and policy relevance. Overall, the methodology represents an effective step toward evaluating and improving the quality of multimodal systems. It equips decision-makers and urban planners with actionable insights to promote high-quality, sustainable transport networks.

5 References

Aguilera-Garcia, A., Gomez, J., & Sobrino, N. (2020). Exploring the adoption of moped scooter-sharing systems in Spanish urban areas. *Cities*, 96, 102424. https://doi.org/10.1016/j.cities.2019.102424

Alessandretti, L., Natera Orozco, L. G., Saberi, M., Szell, M., & Battiston, F. (2023). Multimodal urban mobility and multilayer transport networks. *Environment and Planning B: Urban Analytics and City Science*, 50(8), 2038–2070. https://doi.org/10.1177/23998083221108190

Australian Bureau of Statistics – ABS (2016). *Population Density and Public Transport Map*. Retrieved from https://www.arcgis.com/apps/View/index.html?appid=f937c9d1258d42f7992f748d707a88bc

Barabino, B. (2018). Automatic recognition of “low-quality” vehicles and bus stops in bus services. *Public Transport*, 10(2), 257–289. https://doi.org/10.1007/s12469-018-0180-8

Barabino, B., & Di Francesco, M. (2016). Characterizing, measuring, and managing transit service quality. *Journal of Advanced Transportation*, 50(5), 818–840. https://doi.org/10.1002/atr.1377

Bertolini, L. (1996). Nodes and places: complexities of railway station redevelopment. *European Planning Studies*, 4(3), 331–345. https://doi.org/10.1080/09654319608720349

Calvey, J. C., Shackleton, J. P., Taylor, M. D., & Llewellyn, R. (2015). Engineering condition assessment of cycling infrastructure: Cyclists’ perceptions of satisfaction and comfort. *Transportation Research Part A: Policy and Practice*, 78, 134–143. https://doi.org/10.1016/j.tra.2015.04.031

Currie, G. (2005). The demand performance of bus rapid transit. *Journal of Public Transportation*, 8(1), 41–55. https://doi.org/10.5038/2375-0901.8.1.3

Diana, M., Pirra, M., Castro, A., Duarte, A., Brangeon, V., Di Majo, C., Herrero, D., Hrin, G. R., & Woodcock, A. (2016). Development of an integrated set of indicators to measure the quality of the whole traveller experience. *Transportation Research Procedia*, 14, 1164–1173. https://doi.org/10.1016/j.trpro.2016.05.187

Douglas, N., & Wallis, I. (2013). Predicting the value of public transport in-vehicle time. *Australasian Transport Research Forum 2013 Proceedings*.

Eboli, L., & Mazzulla, G. (2011). A methodology for evaluating transit service quality based on subjective and objective measures from the passenger’s point of view. *Transport Policy*, 18(1), 172–181. https://doi.org/10.1016/j.tranpol.2010.07.007

European Standard EN 13816. (2002). *Transportation – Logistics and Services – Public Passenger Transport – Service Quality Definition, Targeting and Measurement*. European Committee for Standardization, Brussels.

Groenendijk, L., Rezaei, J., & Correia, G. (2018). Incorporating the travellers’ experience value in assessing the quality of transit nodes: A Rotterdam case study. *Case Studies on Transport Policy*, 6(4), 564–576. https://doi.org/10.1016/j.cstp.2018.07.007

Hamerska, M., Ziółko, M., & Stawiarski, P. (2022). A sustainable transport system – The MMQUAL model of shared micromobility service quality assessment. *Sustainability*, 14(7), 4168. https://doi.org/10.3390/su14074168

Hsu, C., Liou, J. J. H., Lo, H., & Wang, Y. (2018). Using a hybrid method for evaluating and improving the service quality of public bike-sharing systems. *Journal of Cleaner Production*, 202, 1131–1144. https://doi.org/10.1016/j.jclepro.2018.08.193

Joumard, R., Gudmundsson, H., & Folkeson, L. (2013). Framework for assessing indicators of environmental impacts in the transport sector. *Transportation Research Record: Journal of the Transportation Research Board*, 2242(1), 55–63. https://doi.org/10.3141/2242-07

Keijer, M. J. N., & Rietveld, P. (2000). How do people get to the railway station? The Dutch experience. *Transportation Planning and Technology*, 23(3), 215–235. https://doi.org/10.1080/03081060008717650

Kosmidis, I., & Müller-Eie, D. (2023). The synergy of bicycles and public transport: A systematic literature review. *Transport Reviews*, 44(1), 34–68. https://doi.org/10.1080/01441647.2023.2222911

Lois, D., Monzón, A., & Hernández, S. (2018). Analysis of satisfaction factors at urban transport interchanges: Measuring travellers' attitudes to information, security and waiting. *Transport Policy*, 67, 49–56. https://doi.org/10.1016/j.tranpol.2017.04.004

Pshinko, O., Charkin, T., Martseniuk, L., & Orlovska, O. (2022). Hubs as a key tool for improving the quality of the service and development of multimodal passenger traffic. *Transport Problems*, 17(1), 201–214. https://doi.org/10.20858/tp.2022.17.1.17

Rahaman, M., Currie, G., & Muir, C. (2016). Development and application of a scale to measure station design quality for personal safety. *Transportation Research Record*, 2540(1), 1–12. https://doi.org/10.3141/2540-01

Solecka, K., Hoy, K. N., & Deryło, A. (2020). Assessment of transport interchanges for the needs of people with reduced mobility. *Travel Behaviour and Society*, 21, 48–56. https://doi.org/10.1016/j.tbs.2020.05.004

Talavera-Garcia, R., & Soria-Lara, J. A. (2015). Q-PLOS developing an alternative walking index. A method based on urban design quality. *Cities*, 45, 7–17. https://doi.org/10.1016/j.cities.2015.03.003

Tanwar, R., & Agarwal, P. K. (2025). Multimodal integration in India: Opportunities, challenges, and strategies for sustainable urban mobility. *Multimodal Transportation*, 100210. https://doi.org/10.1016/j.multra.2025.100210

Transportation Research Board. (2003). *Transit Capacity and Quality of Service Manual* (TCRP Report 100). National Academy Press, Washington, D.C.

Vale, D. S. (2015). Transit-oriented development, integration of land use and transport, and pedestrian accessibility: Combining node-place model with pedestrian shed ratio to evaluate and classify station areas in Lisbon. *Journal of Transport Geography*, 45, 70–80. https://doi.org/10.1016/j.jtrangeo.2015.04.009

Venter, C. J. (2020). Measuring the quality of the first/last mile connection to public transport. *Research in Transportation Economics*, 83, 100949. https://doi.org/10.1016/j.retrec.2020.100949