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TRANSPORT FINDINGS

Site Selection for Future Mobility Hubs in Melbourne: A Multicriteria Location-Allocation Analysis

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Findings

Mobility hubs (MHs) are places offering access to various modes of transport along with enhanced facilities to provide integrated and seamless travel. This study proposes a method to find optimum locations for the planning and development of MHs using Greater Melbourne as a case. Our analysis focuses on 222 existing train stations. We identified 18 stations that meet our operational definition of a mobility hub – i.e., providing interchange facilities for trains, bus/tram, and shared mobility services. The remaining 204 stations were considered as potential candidates for future mobility hubs. These candidates were assessed using location-allocation analysis that optimizes their access for general public, students and commuters travelling by four different modes (car, bike, e-scooter and walking). The shortlisted stations were ranked using a multicriteria scoring system. The analysis resulted in 62 sites with high potential to develop as future mobility hubs.

1. Questions

The concept of mobility hubs (MHs) has emerged as a pivotal solution in augmenting the efficiency of multimodal transportation (Bell 2019). In essence, a multimodal mobility hub is a strategic convergence point equipped with seamless access to various transport modes such as public transport, non-motorized modes, park-and-ride facilities, and shared mobility services. These hubs are enriched with advanced amenities and real-time information, serving not only to enhance the experience of existing users but also to allure and engage new passengers (Arnold et al. 2022).

Strategically positioning a mobility hub in an optimal location is paramount for enhancing transit accessibility and encouraging the adoption of environmentally sustainable transport modes. A few studies have proposed methodologies to identify suitable sites for MHs, leveraging techniques such as network optimization (Alumur, Kara, and Karasan 2012; Zhou, Li, and Zhang 2023) and multicriteria hierarchical analysis (Aydin, Seker, and Özkan 2022; Blad et al. 2022; So et al. 2023). However, the predominant focus has been on pinpointing new optimal locations rather than selecting existing stations for expansion into MHs. This latter approach presents potential advantages, including lower implementation costs and minimal network alterations compared to the construction of entirely new hubs. In response to this gap, our study introduces a novel method aimed at optimizing the identification and selection of transit stations with substantial potential for evolution into future MHs.

2. Methods

2.1. Study area

We implemented our methodology within the extensive public transport networks of the Greater Melbourne Region (GMR), Victoria, Australia, boasting a substantial infrastructure that includes a 250km double track light-rail system (recognised as the world's largest tram network), 24 tram lines, 1630 tram stations, 222 train stations, and 362 bus routes (PTV 2023). Anticipating a remarkable population growth, from current 4.9 million (ABS 2021) to an estimated 9 million by 2056 (Victoria in Future 2019), the Victorian State Government has proactively devised plans to establish future transport hubs. These hubs are envisioned to "support the development of a network of activity centres linked by transport" within the expanding landscape of the GMR, emphasising a strategic response to the region's anticipated growth (Plan Melbourne 2017, 36).

2.2. Identification of existing mobility hubs and candidate sites

Our analysis begins by identifying existing mobility hubs within the GMR. For the purpose of this study, we define an existing mobility hub as a train station with at least two connecting lines (Enbel-Yan and Leonard 2012), functioning as a vital interchange facility for bus/tram within a 150m buffer from the station. Utilising comprehensive public transport data obtained from Public Transport Victoria (PTV 2023), including details on train stations, train lines, bus stops, and tram stops, we identified 18 out of the 222 that met our defined criteria for mobility hubs (Figure 1). Subsequently, the remaining 204 train stations were earmarked as potential candidates for transformation into MHs.

2.3. Determining optimum locations of new mobility hubs

The candidate sites currently fail to meet the definition of a mobility hub and require further interventions such as the introduction of a connecting train line or the placement of a bus/tram interchange facility within a 150m. The question is which of the 204 candidate sites should be prioritised for such interventions. This question is answered by examining two types of potentials for these: a) their ability to cater for more passengers so that the investment return is optimised; and b) their relevance and correspondence with existing policy frameworks.

2.3.1. OPTIMISING THE PATRONAGE

To optimise passenger patronage, we aim to minimise impedance to access the candidate sites for target population within their catchment areas (table 1). As such, we have conducted a maximize-attendance location-allocation analysis using ArcGIS Pro. The location-allocation technique allows to determine the optimal location of facilities by either minimising travel costs/time or maximising service coverage (Cooper 1964). This study used the maximize attendance type, which is often used to locate public transport stations as it considers travel impedance by access mode to maximize demand allocation

Figure 1. Existing mobility hubs in the GMR

Table 1. Assessment scenarios

Scenario	Travel Mode	Target Demand	Spatial Unit	Speed (Km/h)	Catchment area (km)	Distance decay function	Impedance parameter
1	Walking	General public	SA1	5 [1]	1.6	Exponential	-0.2 [3]
2	Cycling	General public	SA1	19 [2]	2	Linear	1
3	Car	General public	SA1	Variable*	6.4	Linear	1
4	E-scooter	General public	SA1	15.5 [2]	3.5	Linear	1
5	Walking	Students	SA1	5 [1]	1.6	Exponential	-0.2 [3]
6	Cycling	Students	SA1	19 [2]	2	Linear	1
7	Car	Students	SA1	Variable*	6.4	Linear	1
8	E-scooter	Students	SA1	15.5 [2]	3.5	Linear	1
9	Walking	Jobs	SA2	5 [1]	1.6	Exponential	-0.2 [3]
10	Cycling	Jobs	SA2	19 [2]	2	Linear	1
11	Car	Jobs	SA2	Variable*	6.4	Linear	1
12	E-scooter	Jobs	SA2	15.5 [2]	3.5	Linear	1

*The speed for car mode is automatically calculated by ArcGIS Pro based on traffic conditions at selected time.
[1] (Bohannon and Williams Andrews 2011); [2] (Arellano and Fang 2019); [3] (Chia, Lee, and Kamruzzaman 2016).

(ArcGIS 2023; Cooper 1964). Further details and the mathematical formulation of the maximum attendance location-allocation type used in this study are available in the supplementary material.

Three distinct groups of potential passengers were considered for the optimisation process: the general public, students, and commuters (measured by the number of jobs). Each group was evaluated against four access modes to the candidate sites (walking, cycling, car and e-scooters), resulting in 12 scenarios (3 groups x 4 modes). The total population, student count, and available jobs accessible from each candidate site were computed, factoring in travel time for the respective transport modes. This study reports the top 10 candidate sites for each scenario.

The values of the different parameters applied to assess the 12 scenarios are provided in Table 1. Population and student count data were available at the statistical area level 1 (SA1), the smallest census boundary in Australia, whereas the number of jobs data were available at the statistical area level 2 (SA2). As a result, access to the candidate stations were calculated at the SA1 level for the general public and student; and the number of jobs reachable from the stations were derived at the SA2 level. A linear decay was assumed for all modes, except for walking, as evidence suggests pedestrians' willingness to use transit is affected exponentially by walking distance (Chia, Lee, and Kamruzzaman 2016).

2.3.2. IDENTIFYING THE RELEVANCE AND CORRESPONDENCE OF THE SHORTLISTED SITES WITH EXISTING POLICY FRAMEWORKS

Following the shortlisting of the top 10 candidate stations, we have ranked them against their relevance and correspondence with existing policy frameworks. To facilitate this ranking, we have employed a multi-criteria evaluation procedure (Table 2). The criteria were applied to derive a hub suitability score (HSS), based on equation 1. The classification of the criteria and their weights are assumed for the purpose of demonstration of the methodology and should be adjusted based on stakeholder consultation.

$$HSS = \sum_{i}^{5} (score_i \times weight_i) \quad (1)$$

3. Findings

Table 3 lists the top 10 candidate train stations per scenario that can be transformed into a mobility hub only based on the demand side factors. Ranking of these stations are also provided in Table 3 as derived through the HSS. Scores against the individual criterion are provided in the supplementary material. The results showed that out of the 204 candidate train stations within the GMR, 62 were shortlisted as suitable mobility hubs across various scenarios. They were found to be scattered across the GMR (i.e., inner, middle and outer). Notably, 15 shortlisted stations appeared in at least three scenarios, with three stations—Armadale, Cheltenham, and Rosanna—standing out by being shortlisted in five scenarios, while Anstey, Jewell, and Ormond secured spots in four scenarios.

Table 2. Scoring system for mobility hub suitability assessment

Parameter	Description	Scoring Criteria	Score	Weight
Proximity to future rail interchanges	Euclidean distance from the shortlisted train stations to their closest future train interchange [1]	Future interchange	3	0.3
		< 1600 m	2	
		1600-3200 m	1	
		> 3200 m	0	
Integration with other public transport modes	Presence of bus/tram link within 150 meters from the shortlisted train stations	Bus and tram	3	0.3
		Tram only	2	
		Bus only	1	
		None	0	
Integration with land use planning	Euclidean distance from the shortlisted train stations to their closest major activity centre as proposed in the Plan Melbourne [2]	< 800m	3	0.2
		800-1600 m	2	
		1600-2400 m	1	
		> 2400 m	0	
Enhancing social equity	Percentage of low-income people within 800 meters from the shortlisted train stations [3]	> 75%	3	0.1
		50-75%	2	
		25-50%	1	
		< 25%	0	
Integration with shared mobility infrastructure	Availability of shared mobility infrastructure (e.g., parking bays, charging stations, and docks) within a 150-meter radius of the train station, accommodating shared micro-mobility (e.g., e-scooters and e-bikes) and/or car-sharing services	Shared micro-mobility and car-sharing	3	0.1
		Shared micro-mobility only	2	
		Car-sharing only	1	
		None	0	

[1] Future planned train network for the Greater Melbourne can be found in Mallis (2023).

[2] For definition of major activity centres, see Plan Melbourme (2017).

[3] We define a low-income person as one with an income that falls below the national median weekly personal income of AUD 805 (ABS, 2021).

Figure 2 shows the train stations with the highest hub suitability scores across all scenarios. Transport planners may firstly consider to upgrade some of those train stations into mobility hubs in order to yield maximum benefits considering all modes and all targeted demand groups together. However, planners must exercise caution and consider concentration effects, especially as some highly suitable stations are in close proximity, such as Clayton and Huntingdale or Coburg and Moreland. While neighbouring stations may individually exhibit high suitability scores, planners should account for appropriate distances when choosing the stations to be upgraded based on the specific project and policy goals. It is worth noting that scenarios focusing solely on cycling and walking as access modes reveal a lower level of spatial clustering, as illustrated in Figure 3. This nuanced observation emphasizes the need for tailored planning approaches based on the specific modes under consideration (figure 3).

Little variation was observed across the scenarios targeting population and student numbers as demand inputs. For instance, nine stations were shortlisted in both scenarios 2 and 6 (cycling), as well as in scenarios 3 and 7 (driving), with a parallel trend of 10 stations shortlisted in both scenarios 4 and 8 (e-scooters).

Table 3. 10 most suitable train stations to be expanded as mobility hubs by scenario.

Ranking Position	Scenarios											
	1	2	3	4	5	6	7	8	9	10	11	12
1	Newmarket (HSS = 1.5)	Cheltenham (HSS = 1.9)	Glen Waverley (HSS = 2.2)	Moreland (HSS = 1.5)	Glenferrie (HSS = 1.4)	Anstey (HSS = 1.2)	Glen Waverley (HSS = 2.2)	Moreland (HSS = 1.5)	Coburg (HSS = 1.6)	Rosanna (HSS = 1.5)	Glen Waverley (HSS = 2.2)	Cheltenham (HSS = 1.9)
2	Anstey (HSS = 1.2)	Anstey (HSS = 1.2)	Clayton (HSS = 2)	Box Hill (HSS = 1.4)	Anstey (HSS = 1.2)	Jacana (HSS = 1.2	Clayton (HSS = 2)	Box Hill (HSS = 1.4)	Rosanna (HSS = 1.5)	Moreland (HSS = 1.5)	Clayton (HSS = 2)	Huntingdale (HSS = 1.9)
3	Windsor (HSS = 1.2)	Jacana (HSS = 1.2)	Cheltenham (HSS = 1.9)	Balaclava (HSS = 1.1)	Flemington Bridge (HSS = 1.1)	Middle Brighton (HSS = 1.2	Cheltenham (HSS = 1.9)	Balaclava (HSS = 1.1)	Collingwood (HSS = 1.5)	Lalor (HSS = 1.4)	Cheltenham (HSS = 1.9)	Rosanna (HSS = 1.5)
4	Noble Park (HSS = 1)	Middle Brighton (HSS = 1.2)	Cranbourne (HSS = 1)	Noble Park (HSS = 1)	Fairfield (HSS = 1)	Springvale (HSS = 1.2	Rosanna (HSS = 1.5)	Noble Park (HSS = 1)	Sunshine (HSS = 1.3)	Blackburn (HSS = 1.1)	Rosanna (HSS = 1.5)	Royal Park (HSS = 1.3)
5	Murrumbeena (HSS = 1)	Springvale (HSS = 1.2)	Keon Park (HSS = 0.9)	Hughesdale (HSS = 0.9)	Murrumbeena (HSS = 1)	Mount Waverley (HSS = 1.1)	Cranbourne (HSS = 1)	Hughesdale (HSS = 0.9)	Brunswick (HSS = 1)	Mount Waverley (HSS = 1.1)	Leawarra (HSS = 1)	Gardenvale (HSS = 1)
6	Ormond (HSS = 0.8)	Mount Waverley (HSS = 1.1)	Keilor Plains (HSS = 0.9)	Ascot Vale (HSS = 0.8)	Ascot Vale (HSS = 0.8)	Preston (HSS = 1.1)	Keon Park (HSS = 0.9)	Ascot Vale (HSS = 0.8)	Nunawading (HSS = 1)	Boronia (HSS = 1)	Albion (HSS = 0.7)	Leawarra (HSS = 1)
7	Armadale (HSS = 0.6)	Preston (HSS = 1.1)	South Morang (HSS = 0.8)	Ormond (HSS = 0.8)	Ormond (HSS = 0.8)	Gardenvale (HSS = 1)	Keilor Plains (HSS = 0.9)	Ormond (HSS = 0.8)	East Malvern (HSS = 0.7)	Moorabbin (HSS = 0.6)	Thomastown (HSS = 0.7)	Glen Iris (HSS = 0.8)
8	Ripponlea (HSS = 0.6)	Gardenvale (HSS = 1)	Werribee (HSS = 0.8)	Armadale (HSS = 0.6)	Armadale (HSS = 0.6)	Hampton (HSS = 0.8)	South Morang (HSS = 0.8)	Armadale (HSS = 0.6)	Armadale (HSS = 0.6)	Upfield (HSS = 0.6)	Sandown Park (HSS = 0.6)	Upfield (HSS = 0.6)
9	Croxton (HSS = 0.5)	Patterson (HSS = 0.7)	Watsonia (HSS = 0.4)	Jewell (HSS = 0.5)	Ripponlea (HSS = 0.6)	Patterson (HSS = 0.7)	Werribee (HSS = 0.8)	Jewell (HSS = 0.5)	Canterbury (HSS = 0.6)	Westall (HSS = 0.6)	Upfield (HSS = 0.6)	Bell (HSS = 0.5)
10	Jewell (HSS = 0.5)	Parkdale (HSS = 0.5)	Oak Park (HSS = 0.3)	Thornbury (HSS = 0.5)	Jewell (HSS = 0.5)	Parkdale (HSS = 0.5)	Oak Park (HSS = 0.3)	Thornbury (HSS = 0.5)	Narre Warren (HSS = 0.4)	Narre Warren (HSS = 0.4)	Narre Warren (HSS = 0.4)	Laburnum (HSS = 0.4)

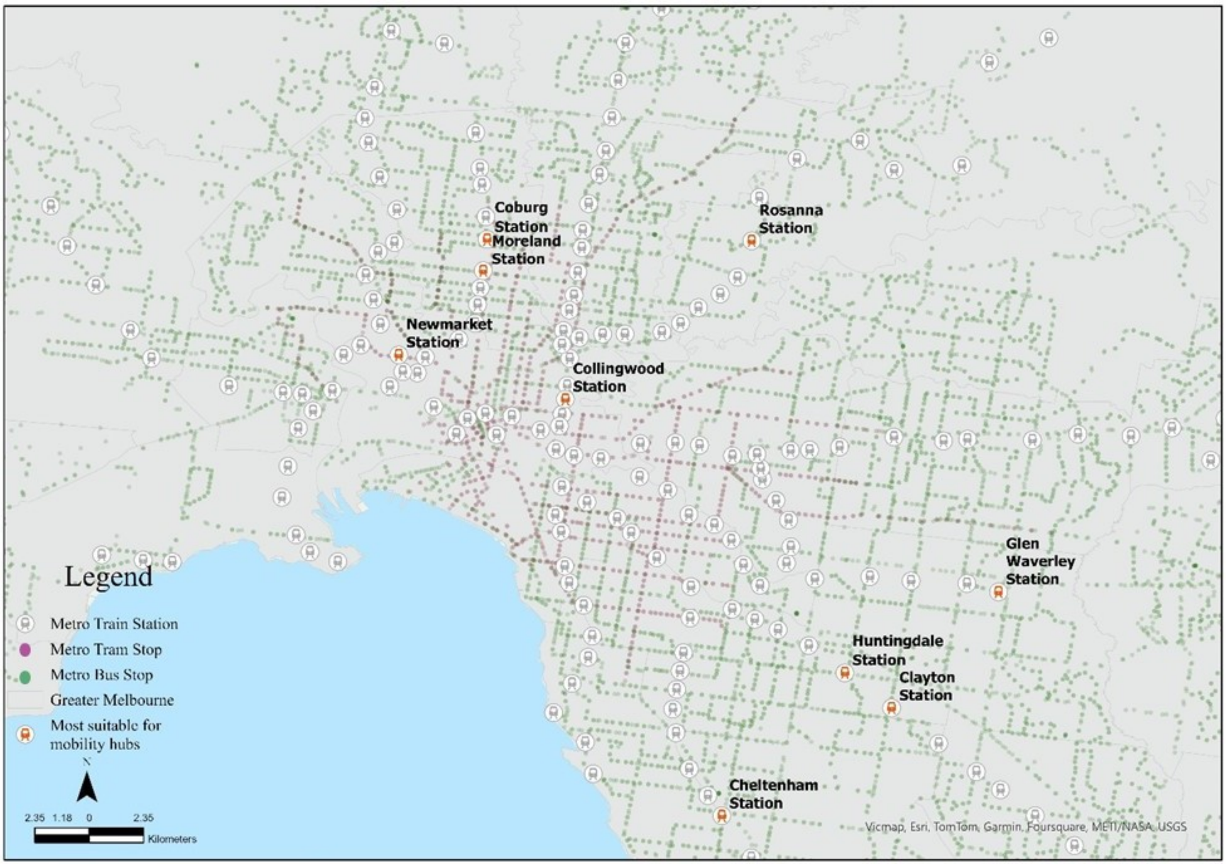

Figure 2. Most suitable locations for new mobility hubs considering all scenarios

On the other hand, scenarios involving jobs exhibited larger variations compared to those centred on population or students. For example, only one station was shortlisted in both scenarios 1 and 9 (walking), while none were selected in both scenarios 2 and 10 (cycling) or scenarios 4 and 12 (e-scooters). These variations can be attributed to the distinct characteristics of demand points, especially given the dual inclusion of students in both population and student datasets. An intriguing finding emerges when students were excluded from the analysis due to their high correlation with population, resulting in the shortlisting of five stations across at least three scenarios. This underscores the nuanced interplay between demand factors and the need for a refined understanding of dataset dynamics in mobility hub planning.

The findings stratified by mode offer transport planners the opportunity to strategically plan mobility hubs to attract commuters based on their primary modes of transportation. As a result, mobility hubs could be implemented to enhance the use of park-and-ride in car-oriented areas, improve e-scooter feasibility in low-density areas as well as promote walking and cycling. The scenario-based method in conjunction with the location-allocation analysis used in this project may also be a powerful and easy-to-use tool for transport planners. The method proposed in this study could also be applied to other modes (e.g., autonomous vehicle and e-bikes) and other target demand types (e.g., elderly, people with disabilities, women).

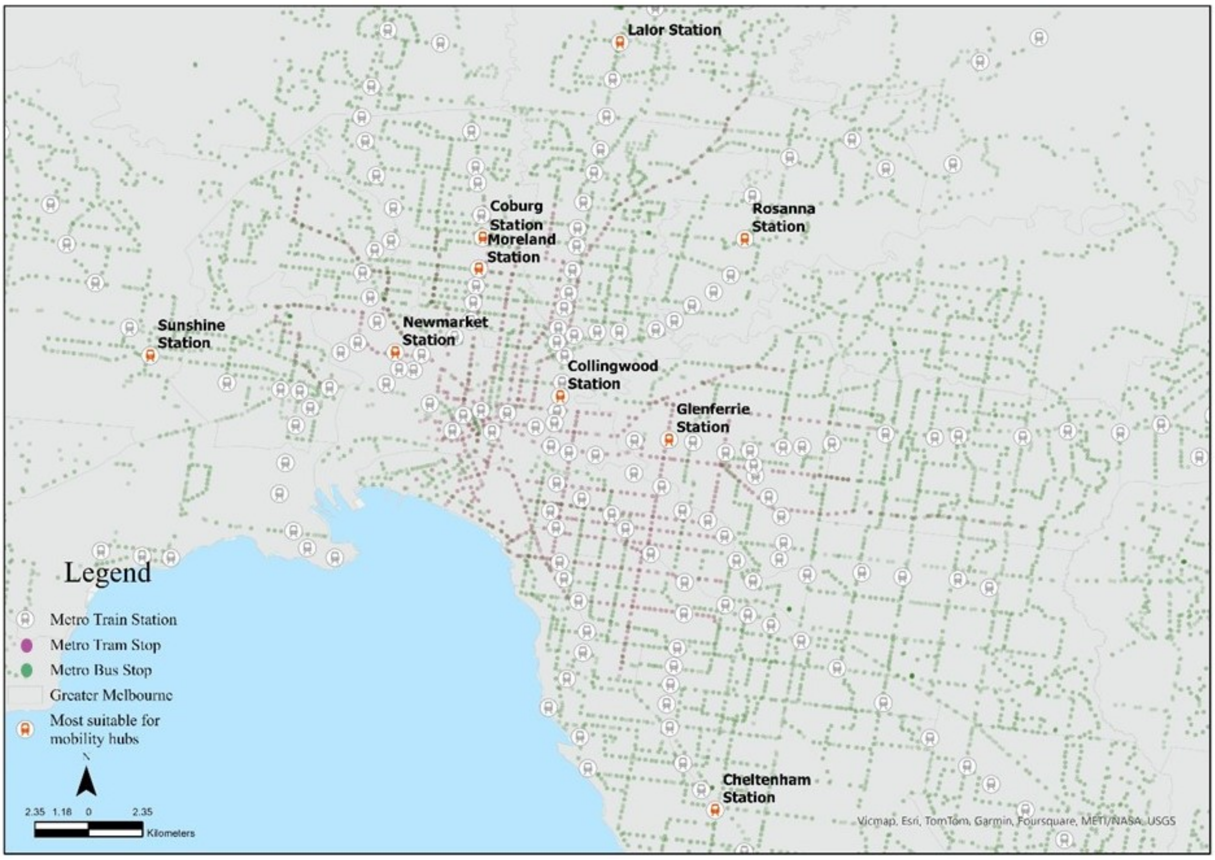

Figure 3. Most suitable locations for new mobility hubs considering only scenarios with walking and cycling as access modes

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SUPPLEMENTARY MATERIALS

Supplementary Material

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