A Multi-Criteria GIS Approach to Evaluate Transit Accessibility Index: Integrating FAHP in Suburban Malaysia

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Abstract

Transit accessibility plays a pivotal role in shaping mobility equity and urban sustainability, particularly in rapidly developing suburban environments where formal public transport infrastructure is often fragmented. This study presents a novel GIS-based Transit Accessibility Index (TAI) model integrating Fuzzy Analytic Hierarchy Process (FAHP) with Weighted Overlay Analysis (WOA) to assess transit service equity in Puncak Alam, Malaysia. Nine spatial criteria namely job density, land use, travel time, frequency, reliability, and demographic vulnerability were evaluated using expert-derived fuzzy weights and reclassified into a common scale using Jenks natural breaks. A consistency ratio check (CR = 0.088) validated the reliability of the expert judgment matrix. Site verification confirmed that high TAI zones, such as Alam Suria and Sungai Buloh, correspond with dense transit infrastructure, while low-accessibility areas exhibited limited-service coverage and unfavourable demographic or land use profiles. A sensitivity analysis adjusting the weight of the "age" criterion demonstrated the model's robustness, with minimal impact on spatial outcomes. The study offers a reproducible, adaptable framework for transit equity assessment in suburban contexts and informs data-driven planning for future Transit-Oriented Development (TOD) and last-mile service optimization. Findings support the integration of FAHP-GIS models in accessibility planning and contribute to the advancement of spatial equity methodologies in emerging urban peripheries.

1. Introduction

Urban sprawl and rapid development of cities have posed significant challenges for sustainable mobility, particularly in developing countries. The increased reliance on private vehicles has contributed to higher greenhouse gas (GHG) emissions, traffic congestion, and deteriorating air quality, with non-exhaust emissions accounting for 70% of air pollution-related deaths (Roy et al., 2024). Promoting public transportation as an alternative to private vehicles is thus critical to achieving sustainability goals, notably Sustainable Development Goal 9 (SDG 9), which emphasizes inclusive urban infrastructure development for diverse community needs, including persons with disabilities (PwD), as well as enhancement of micro-mobility in First-Last Mile (FLM) of the public transportation usage (Roslan & Naharudin, 2023).

Accessibility is the ease with which people can reach desired goods, services, and activities that are fundamental indicators in transportation and urban planning (Jones, 1981; Clifton et al., 2008). Various methods have been developed to measure transit accessibility, including distance-based models (Hansen, 1959), cumulative opportunity models (Dalvi & Martin, 1976), gravity models (Weibull, 1980), and composite indices like Public Transport Accessibility Levels (PTAL). However, many of these models assume the presence of well-developed transit systems and dense urban environments, which may not accurately represent the realities of rapidly urbanizing suburban areas. Furthermore, traditional models often struggle to account for uncertainty and subjective expert judgment in defining accessibility criteria and their relative importance.

In Malaysia, the urban population is projected to reach 84% by 2040, intensifying the need for efficient, equitable public transportation systems. Puncak Alam, a rapidly growing township with limited direct access to rail or mass transit systems, exemplifies this challenge. Despite substantial population growth, the area remains heavily reliant on private vehicles, exacerbating fossil fuel consumption and hindering Malaysia's ambition of achieving net-zero emissions by 2050 (National Energy Transition Roadmap, 2023).

Given the limitations of traditional transit accessibility measurement approaches, this study adopts a Fuzzy Analytical Hierarchy Process (FAHP) framework to assess the Transit Accessibility Index (TAI) for Puncak Alam. FAHP is particularly suited for contexts with incomplete transit infrastructures and ambiguous service quality, as it enables capturing the subjective preferences of policymakers and urban planners while accommodating uncertainty in decision criteria weighting.

Despite growing awareness of the importance of transit accessibility for sustainable urban development, many suburban and rapidly urbanizing areas like Puncak Alam remain underserved by public transportation infrastructure (Kalhoro, 2023). Traditional transit accessibility models such as cumulative opportunity, gravity-based, or PTAL methods primarily cater to well-established urban cores, often neglecting low-density, car-dependent suburbs with evolving transport needs. Moreover, conventional weighting techniques used in accessibility evaluation tend to rely on deterministic assumptions, failing to account for uncertainties and subjective priorities among diverse stakeholder groups such as urban planners, policymakers, and residents.

This pilot study aims to develop and test a customized TAI model integrating spatial data with FAHP-derived accessibility weights, providing a structured methodology for identifying service gaps and informing future public transit planning in Puncak Alam. The findings will not only contribute to localized urban mobility solutions but also offer insights applicable to similar suburban and peri-urban regions facing rapid growth and limited transit connectivity.

2. Methodology

2.1 Study Area

Figure 1 shows the selected study area which is Puncak Alam that is in the district of Kuala Selangor, Selangor, Malaysia, has emerged as one of the fastest-developing suburban townships within the Klang Valley conurbation. Strategically situated northwest of Kuala Lumpur, the area has experienced rapid urbanization driven by the expansion of residential zones, commercial hubs, and educational institutions.

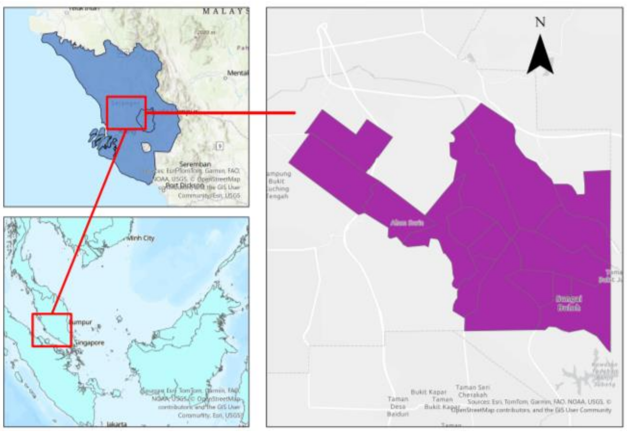

Figure 1. Study Area

Despite its demographic and infrastructural growth, the area remains critically underserved by high-capacity public transportation systems. Presently, public transit services are limited to local bus operations, with no direct link to the existing rail-transit networks. As such, the mobility of residents is highly dependent on private vehicles, resulting in increased congestion, car ownership, and environmental externalities.

Puncak Alam is accessible via major expressways including the Guthrie Corridor Expressway (GCE), the North–South Expressway Central Link (ELITE), and the Kuala Lumpur–Kuala Selangor Expressway (LATAR), reinforcing its role as a key suburban corridor. However, this road-centric connectivity exacerbates transport inequalities, particularly for residents without access to private transport, elderly populations, and low-income groups.

The township exemplifies a transitional urban setting shifting from low-density, peri-urban land use towards a more consolidated urban form yet lacking the transit infrastructure necessary to support sustainable urban mobility.

This context makes Puncak Alam an ideal pilot case for evaluating transit accessibility through an integrated, criteria-driven spatial framework. The study area presents a dynamic interplay of development pressures, infrastructural gaps, and socio-spatial disparities that require a robust and adaptable analytical approach.

By focusing on Puncak Alam, this study aims to explore how spatially differentiated access to transit services can be quantitatively assessed and visualized using Multi-Criteria Decision Analysis (MCDA) and GIS techniques. The insights derived from this case study are expected to inform regional planning strategies and TOD policies applicable to other rapidly urbanizing suburban settings in Malaysia and across the Global South.

2.2 Data Used

Table 1 shows the data required in conducting this study as well as their sources.

Data	Source
Landsat 8	USGS Earth Explorer
Point of Interest (shop, etc)	OpenStreetMap
Job Density	POI
Road	OpenStreetMap
Demographic	DOSM
Report of Transit Incident	Published news or reports

Table 1. Data.

2.3 Methods

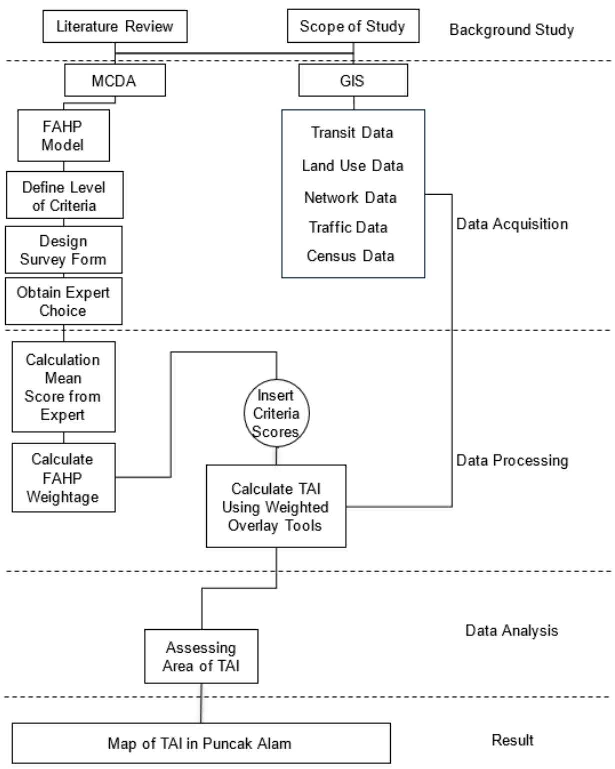

Figure 2. Methodological framework for assessing TAI

This study adopts a five-phase methodological framework FAHP, spatial data modelling, and GIS to construct a TAI tailored to the suburban context of Puncak Alam. The workflow is designed to ensure methodological transparency, context sensitivity, and empirical reliability, incorporating both expert knowledge and spatial analysis to assess transit accessibility performance. The five phases consist of background study, data acquisition, data processing, data analysis, and output generation. The overall methodological flow is illustrated in Figure 2.

The methodological framework for assessing TAI in Puncak Alam consists of five sequential phases. Phase 1 involved a background study and literature review to identify key accessibility criteria and justify the adoption of a FAHP-GIS approach. Phase 2 focused on data acquisition, including expert surveys and spatial datasets such as transit routes, land use, population, and socioeconomic proxies. In Phase 3, data processing was carried out by computing FAHP weights through fuzzy pairwise comparison and integrating the standardized criteria layers using Weighted Overlay Analysis (WOA) in ArcGIS. Phase 4 comprised data analysis, including interpretation of the TAI map and site verification to validate modelled results with real-world transit conditions. Finally, Phase 5 produced the TAI performance map, classifying accessibility into five levels and providing a spatial tool to support evidence-based transit planning and equity assessment in suburban contexts.

2.3.1 Criteria Selection and Justification: The development of robust TAI requires the careful selection of criteria that comprehensively capture the spatial, temporal, and socioeconomic dimensions of access to public transportation. Based on an extensive review of relevant literature (Buonocore et al., 2023) and tailored to the suburban context of Puncak Alam, nine criteria were selected and grouped into four categories: attractiveness of opportunities, transport service quality, temporal accessibility, and socioeconomic equity.

Land use represents spatial distribution and functional diversity of built environments, with greater land use heterogeneity associated with increased transit utility and reduced car dependence (Zhang & Zhang, 2018). Job density reflects the spatial concentration of employment opportunities and was modeled based on POI and commercial land use data (Guzman & Cardona, 2021). Frequency of service measures how often public transit is available along a route, reducing waiting time and improving user satisfaction (Shi et al., 2023), while reliability captures consistency in service provision through route duplication and detour metrics. Waiting time represents the interval between transit arrivals and affects perceived cost, especially among low-income and elderly users (El-Geneidy et al., 2006). Travel time reflects total journey duration and was calculated using shortest paths in ArcGIS Network Analyst (Bhellar et al., 2023). Income, as a critical equity-focused criterion, was estimated using spatial proxies such as road density and housing types (Loh & Kim, 2021). Population density, derived from DOSM census data, indicates potential ridership, while age distribution addresses the needs of elderly populations and supports SDG 11 (Jahangir et al., 2024).

Each criterion was spatially processed, normalized, and integrated in the GIS-based model to ensure the TAI addresses both service distribution and social equity in Puncak Alam.

2.3.2 FAHP Weight Derivation: To determine the relative importance of the transit accessibility criteria, this study employed FAHP, a decision-making technique that combines the analytical hierarchy structure of AHP with fuzzy set theory to better manage uncertainty and subjectivity in expert judgments.

FAHP is particularly appropriate in transportation planning contexts where expert opinions may vary due to limited data, spatial heterogeneity, or evolving policy priorities. A structured pairwise comparison form was developed using nine criteria identified from literature and contextualized for the Puncak Alam case study: land use, job density, frequency of service, waiting time, reliability, income, population, travel time, and age.

In this pilot study, expert judgment was obtained from a research officer from a national road safety research organization. The expert was selected based on their domain expertise in transport planning, spatial analysis, and decision-making frameworks. The direct involvement in national mobility projects and familiarity with suburban transit challenges in Malaysia made the expert well-qualified to provide the weighting of accessibility criteria.

The expert provided judgments using linguistic terms mapped to Triangular Fuzzy Numbers (TFNs) according to standard Saaty scales such as “equally important,” “moderately more important,” and “strongly more important”. Chang’s extent analysis method (Chang, 1996) was applied to compute the fuzzy synthetic extent values for each criterion. The procedure involved four main steps: construction of a fuzzy pairwise comparison matrix, computation of fuzzy synthetic extent values for each criterion, calculation of the degree of possibility between pairs of criteria, and defuzzification using the centroid (center-of-area) method to obtain crisp values, followed by normalization.

The final FAHP weights showed job density (24%), land use (19%), travel time (15%), and reliability (12%) as the most influential criteria, while population, and age each held a lower weight of 4%. These weights were used in the GIS-based WOA to compute the final TAI map.

Criterion	Percentage Weight
Job Density	24
Land Use	19
Travel Time	15
Reliability	12
Waiting Time	9
Frequency	8
Income	5
Population	4
Age	4

Table 2. Expert Final Weightage

Using Consistency Ratio (CR) in equation 1 to calculate the CR value for expert in this study. Random Index (RI) value depends on the number of criteria. Based on number of criteria, the value of RI is identified in RI table.

$$CR = \frac{CI}{RI} \quad (1)$$

where CR = Consistency Ratio
CI = Consistency Index
RI = Random Index

As only one expert was consulted in this preliminary study, aggregation of multiple expert judgments was not applicable. However, CR check was conducted on the resulting fuzzy matrix. The computed CR value was 0.088, which falls within the acceptable threshold (< 0.10), indicating internal logical consistency of the expert’s evaluations. Since divergent judgments were not applicable in this single-expert case, no reconciliation process was required. Nonetheless, future full-scale studies will incorporate multiple expert inputs, each subjected to individual CR validation. Final weights will be aggregated using consensus techniques or post-normalization averaging, as supported in FAHP methodological literature.

Although FAHP-GIS approaches have been widely applied in transit accessibility studies, this research introduces several methodological enhancements that distinguish it from conventional frameworks. First, the FAHP criteria weights are designed to be modular and updatable, enabling future integration of time-sensitive expert inputs as transit conditions evolve. This allows for dynamic re-weighting based on policy shifts or urban form changes, aligning the model with adaptive decision-making needs in fast-developing suburban contexts. Second, the GIS-based model is structured to accommodate integration of live General Transit Feed Specification (GTFS) data, enabling future adaptation to real-time transit scheduling and service frequency changes. Although GTFS was not implemented in this pilot study, the framework anticipates this enhancement as part of a planned scalability phase. These innovations support a more responsive and context-sensitive evaluation of transit accessibility, addressing the temporal limitations of static FAHP-GIS models.

2.3.3 TAI Modelling with WOA: The final step in developing TAI involved the integration of all spatially processed criteria using WOA method within a GIS environment. This approach allows for the combination of multiple raster-based data layers, each representing a standardized accessibility criterion, according to the relative weights derived through the FAHP. Each of the nine selected criteria land use, job density, frequency of service, waiting time, reliability, income, population, travel time, and age was first normalized to a common scale. This standardization ensures compatibility across datasets with different units and measurement scales. Reclassification was performed using the Natural Breaks (Jenks) method to preserve the inherent structure of the data distribution while minimizing within-class variance (Yavas et al, 2024).

The FAHP-derived weights were then applied to each criterion layer. These weights reflect the expert judgment, emphasizing the importance of job density, land use, travel time, and reliability as the dominant determinants of transit accessibility in Puncak Alam respectively. The final TAI value for each raster cell (x,y) was computed using the weighted linear combination model. The composite TAI surface was classified into five accessibility performance levels: Very High, High, Moderate, Low, and Very Low, using the Jenks Natural Breaks classification. The resulting TAI map provides a spatially explicit visualization of transit accessibility performance across Puncak Alam, highlighting areas of high accessibility near dense employment centres and public facilities, and exposing low-accessibility zones in peripheral residential areas.

To ensure comparability across the nine selected criteria layers, each raster was standardized to a common ordinal scale ranging from 1 (Very Low) to 5 (Very High) prior to integration in WOA. Although no mathematical normalization equation (such as min-max scaling) was applied, each criterion layer was manually classified based on its thematic interpretation and spatial relevance. Reclassification followed a conceptual framework that distinguishes between positive and negative accessibility indicators.

Reclassified scores where higher raw values represent favourable transit accessibility such as job density, land use intensity (urban areas), frequency of service, population density, and income are higher for criteria indicated better accessibility conditions. Conversely, for criteria where higher raw values indicate accessibility challenges such as longer travel time, longer waiting time, low service reliability, and age concentration (elderly or dependent population), the reclassification was inversely applied, with higher raw values assigned lower scores.

Using the Jenks Natural Breaks method in ArcGIS, which optimizes class intervals by minimizing intra-class variance, all nine raster layers were reclassified into five ordinal classes. Each layer was classified individually with five classes, corresponding to: Very Low (1), Low (2), Moderate (3), High (4), and Very High (5). This approach preserved the natural data distribution within each criterion while aligning with the FAHP-based multi-criteria structure of the model. The reclassified raster was then weighted using the FAHP-derived criteria weights to generate the composite TAI surface for the study area.

3. Result and Discussion

3.1 Overview of TAI Spatial Distribution

The TAI performance map generated through FAHP-WOA provides a detailed spatial overview of transit accessibility across the Puncak Alam study area (Figure 3).

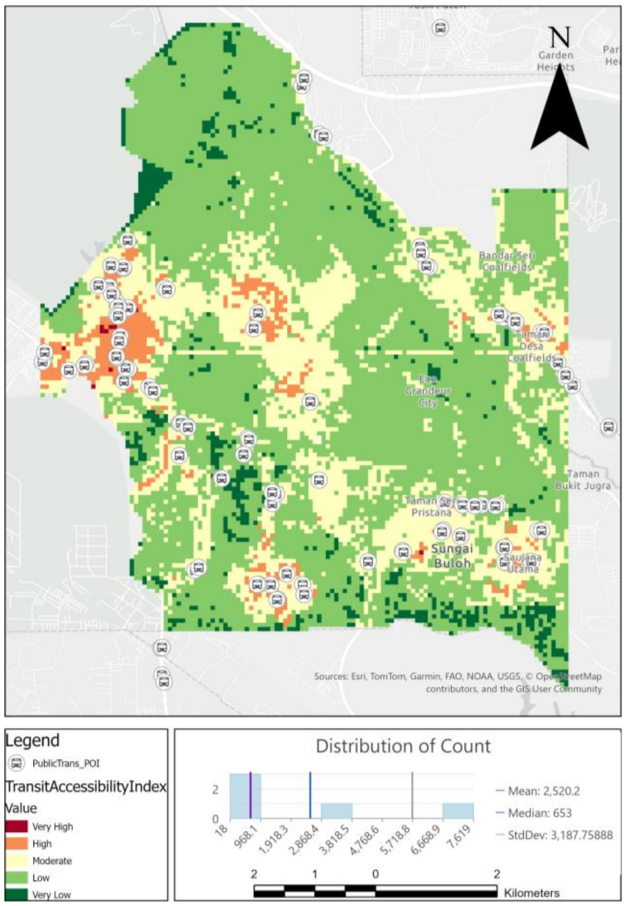

Figure 3. TAI Performance Map

The analysis reveals a predominantly moderate to high level of accessibility throughout central Puncak Alam, with distinct clusters of very high accessibility observed in areas such as Alam Suria, Sungai Buloh, and the southern corridor near

Bandar Seri Coalfields. These zones are characterized by a confluence of favourable factors, including proximity to public transit stops, dense job clusters, younger age demographics (majority population below 65), and short travel times. Notably, these high-performing areas also intersect with low reliability scores an inverse metric in this context indicating stable and predictable service patterns with minimal disruption reports.

Conversely, low and very low accessibility zones are mainly located along the periphery of the study area, particularly in sparsely developed northern and western sectors. These zones often coincide with greater distances from transit infrastructure, limited land use diversity, lower job density, and elevated travel times. The distribution analysis also shows that transit accessibility is not uniform but rather spatially fragmented, reinforcing the need for localized accessibility interventions. The distribution histogram indicates a right-skewed pattern, with the mean TAI value at 2,520.2 and a median of 653, suggesting that while a few areas benefit from excellent accessibility, a substantial portion of the study area remains underserved.

3.2 High Accessibility Zones

The very high and high accessibility zones identified in the TAI map are predominantly concentrated in the central and southern areas of Puncak Alam, particularly around Alam Suria, Sungai Buloh, and the peripheries of Eco Grandeur City and Bandar Seri Coalfields. These zones demonstrate a strong alignment between high composite TAI scores and favourable accessibility conditions, corroborated by the spatial intersection of key contributing factors.

One of the most prominent drivers of high accessibility performance is proximity to public transit infrastructure. As shown in Figure 4 of public transit overlay map, high TAI zones tend to coincide with dense clusters of bus stops and transit nodes, particularly along major corridors that connect to institutional, commercial, and residential centres. Job density is another dominant factor in these zones, consistent with its highest FAHP weight (24%) in the model which is shown in Figure 5.

Areas such as Sungai Buloh and Alam Suria host numerous commercial and institutional facilities, which not only generate demand but also justify more frequent service provision. In addition, travel time (Figure 6) plays a critical role in shaping the accessibility landscape. Reliability as shown in Figure 7, modelled as an inverse metric in this study, further strengthens the interpretation.

Finally, demographic composition, specifically the proportion of population under the age of 65, intersects significantly with high TAI zones. These spatial patterns validate the TAI model's sensitivity to local urban conditions and demonstrate that high transit accessibility in Puncak Alam is the result of a multi-dimensional synergy between service proximity, job concentration, travel efficiency, and operational stability.

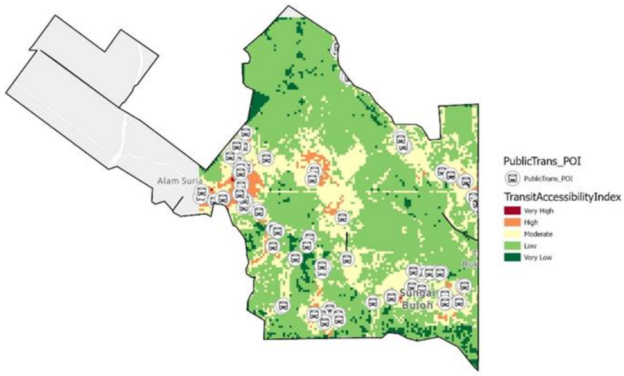

Figure 4. Public Transit Overlay Map

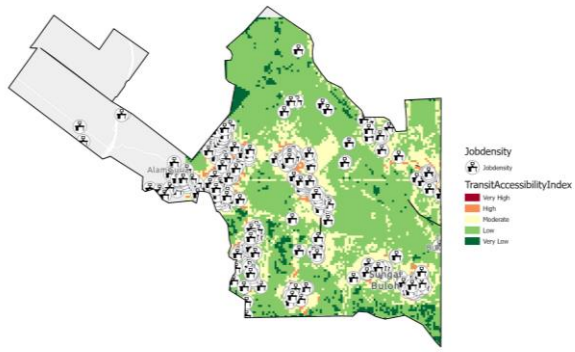

Figure 5. Job Density Overlay Map

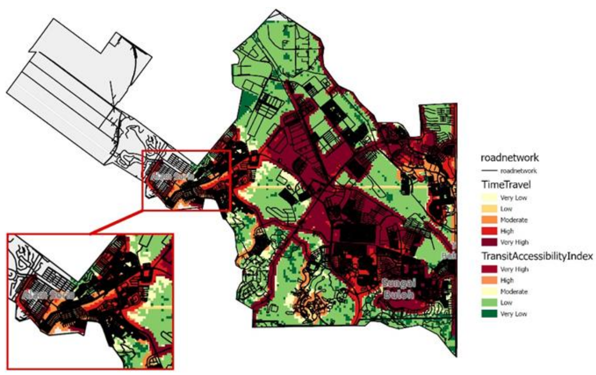

Figure 6. Travel Time Overlay Map

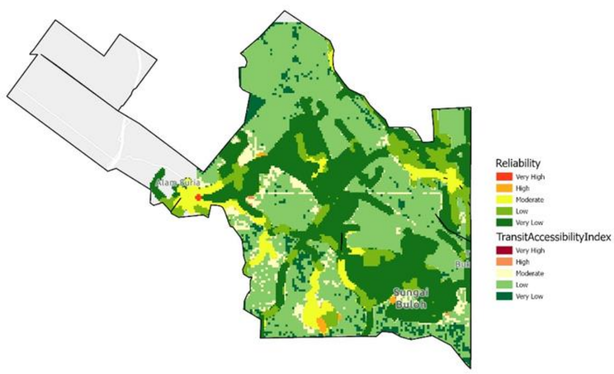

Figure 7. Reliability Overlay Map

3.3 Low Accessibility Zones

In contrast to the well-served high-accessibility clusters, several regions across Puncak Alam exhibit low and very low TAI scores, indicating substantial transit service gaps. These zones are mainly located on the northern and western periphery, including areas near Kampung Merbau, Bandar Saujana Utama, and areas of eastern Puncak Alam that are distant from the primary transport corridors.

A key factor contributing to poor accessibility in these zones is the limited proximity to public transit infrastructure. As visualized in Figure 4, the outer residential sectors are largely disconnected from formal bus stops or high-frequency service routes. These spatial voids result in longer first-mile travel distances, reduced service reliability, and a diminished incentive to shift from private vehicle use to public transit.

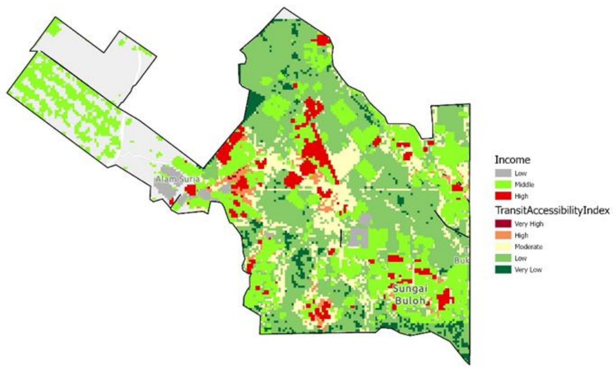

Figure 8. Income Overlay Map

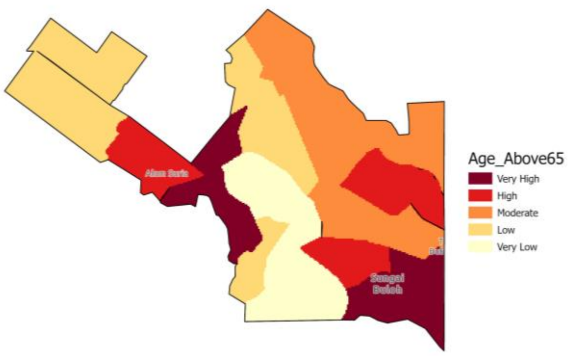

Figure 9. Age Above 65 Map

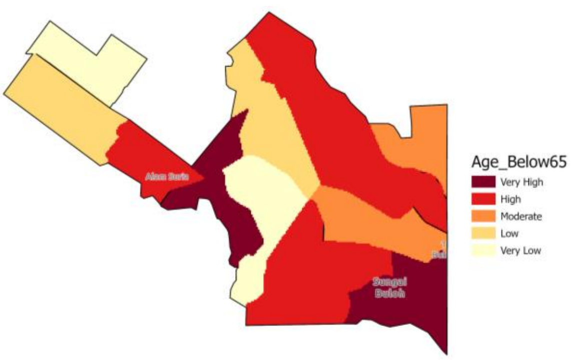

Figure 10. Age Below 65 Map

Based on the income surface map (Figure 8), many of the low-TAI areas overlap with middle- to low-income households, suggesting a mismatch between transit needs and service provision. Populations in these zones may face financial and physical constraints in accessing alternative modes of transportation, thereby exacerbating transport-related social exclusion. Although income held a lower FAHP weight (5%), its intersection with poorly served areas highlights the equity implications of accessibility disparities.

The age maps indicate that some low-accessibility areas coincide with a higher proportion of elderly residents (age 65 and above) in Figures 9 and 10, who are typically more transit-dependent due to reduced driving capacity and higher vulnerability. Another observable pattern is the dispersed land use and low job density (Figure 5) in these areas, which weakens the justification for transit investments under conventional demand-based models.

The combination of physical remoteness, modest socioeconomic conditions, and aging populations make these zones especially vulnerable to transport disadvantages. Their exclusion from core transit service networks suggests an urgent need for interventions such as demand-responsive transport (DRT), improved feeder services, or non-motorized infrastructure enhancements.

3.4 Sensitivity Analysis

To evaluate the robustness of the TAI model, a simple one-factor sensitivity analysis was performed by modifying the percentage weights assigned to each criterion in the WOA. The original FAHP-derived weights, as shown in Table 3, were based on expert judgment. In the sensitivity scenario, the weight of the Age criterion was substantially increased (from 4% to 20%), while the weights of other criteria particularly Income, Population, Waiting Time, and Frequency were proportionally reduced. This modified weighting scheme tests the influence of age vulnerability on the resulting TAI distribution. Both the original expert weightage and adjusted weight for sensitivity analysis is shown in Table 3.

Criterion	Original Weight (%)	Adjusted Weight (%)
Job Density	24	22
Land Use	19	17
Travel Time	15	13
Reliability	12	10
Waiting Time	9	7
Frequency	8	6
Income	5	3
Population	4	2
Age	4	20

Table 3. Result of FAHP Sensitivity Analysis

Figures 11 and 12 show the difference between original TAI map and adjusted TAI map. The modified weights were applied to the same set of reclassified raster layers in ArcGIS using the Weighted Overlay tool. The spatial results showed that while certain zones experienced minor changes in their TAI classification particularly in the northern and central parts of the study area overall pattern of accessibility remained largely consistent. As shown in the sensitivity map emphasizing the age criterion, some shifts in accessibility categories occurred in areas with higher elderly population concentration, such as the outskirts of Bandar Seri Coalfields (blue box) and Bandar Alam Bangsa (red box).

However, high-accessibility zones like Alam Suria and Sungai Buloh both identify in the map (orange box) retained their classification, confirming the persistence of core accessibility patterns. The distribution histogram also reflects similar statistical behaviour in terms of class distribution and central tendency, with minimal changes in mean and standard deviation. This outcome reinforces the model's internal stability and suggests that the TAI framework is not overly sensitive to isolated changes in individual criterion weights, particularly when the underlying spatial conditions remain constant.

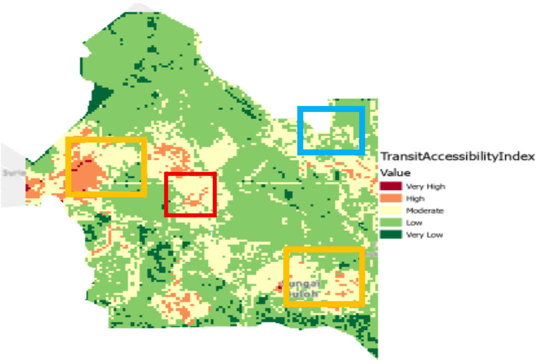

Figure 11. TAI Map with Original Weight

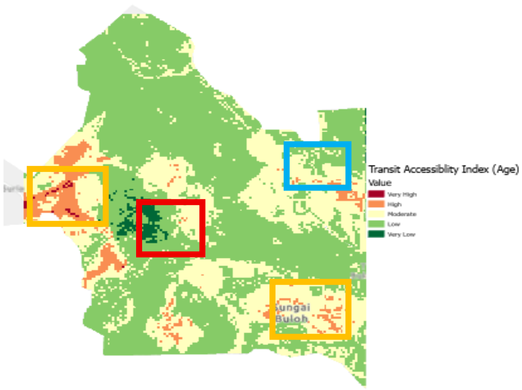

Figure 12. TAI Map with Adjusted Weight

3.5 Site verification

In order to further verify the result of this study, TAI model is validate using site verification. This is to verify some spatial data uses as criteria is available on the map and on site is align with each other. The purpose of this exercise was to assess whether the TAI results correspond with actual physical and environmental conditions on the ground, particularly in terms of transit infrastructure, service availability, and land use integration.

In high-TAI zones such as Alam Suria (Figure 13) and Bandar Saujana Utama (Figure 14), field observations affirmed the presence of multiple key accessibility elements: well-marked and sheltered bus stops, pedestrian pathways, high-frequency service corridors, and proximity to commercial hubs and employment centres. The physical infrastructure in these areas such as route signage, shelters, and walkable access strongly aligned with model predictions. For instance, the availability of direct access to bus services, integrated with public facilities and retail outlets near the Alam Suria Mosque and commercial complex, supported the model's classification of the area as "Very High Accessibility."

Moderate-TAI areas, such as the vicinity of local hypermarket in Alam Suria in Figure 15, exhibited mixed conditions. While public transport infrastructure existed, it was less integrated such as bus stops were spaced farther apart, and service information was limited. These conditions, suggesting that spatial availability alone does not ensure optimal accessibility without supporting amenities or other criteria such as housing area and population justify the model's moderate rating.

Figure 13. Bus Stop at Alam Suria

Figure 14. Bus Stop at Bandar Saujana

Figure 15. Bus Stop at Alam Suria's local hypermarket

Conversely, in low-TAI areas like Eco Grandeur (Figure 16), site visits confirmed an absence of essential infrastructure. These areas, characterized by mono-functional residential development with limited job density and commercial activity had minimal or no bus stop coverage, lacked pedestrian connectivity. Despite having moderate population density, the lack of transit integration resulted in real-world inaccessibility validating the model's output.

Figure 16. Residential Area at Eco Grandeur

In summary, the site verification results corroborate the spatial outputs of the FAHP-GIS based TAI model. High-index areas reflected dense, mixed-use development and transit infrastructure proximity, while low-index zones were associated with transit voids, poor service coverage, and land use limitations. These ground-truthing exercises reinforce the reliability of the TAI as a diagnostic tool and highlight its potential to inform planning interventions in rapidly urbanizing suburban environments like Puncak Alam.

4. Conclusion

This study demonstrates the feasibility and utility of a MCDA approach using FAHP integrated with GIS to evaluate transit accessibility in a rapidly urbanizing suburban context. By applying the model in Puncak Alam, Malaysia which is a township experiencing dynamic land use change and increasing transport demand but limited formal transit infrastructure. The research addresses a critical gap in suburban transit planning in Puncak Alam. The development of TAI offers a replicable framework for identifying spatial disparities (Jang et al, 2017) in transit service provision, integrating land use, transport service quality, and socioeconomic equity dimensions into a composite spatial indicator.

The findings of this study reveal that zones with very high TAI values, such as Alam Suria and Sungai Buloh, are characterized by a convergence of dense job clusters, well-distributed public transport stops, lower travel times, and lower age-based vulnerability. Conversely, peripheral areas like Eco Grandeur exhibit lower accessibility scores due to its physical remoteness, sparse land use mix, and lack of supporting transit infrastructure. These spatial patterns underscore the model's sensitivity to the interplay between built environment, service frequency, and demographic vulnerability which validating the inclusion of both physical and social criteria in accessibility analysis.

An important contribution of this study lies in its methodological innovation. The FAHP model used here is tailored for suburban realities, allowing weights to be derived under uncertainty using linguistic judgments converted into fuzzy triangular numbers. The incorporation of a consistency ratio check (CR = 0.088) ensures the internal validity of expert input, while the potential for integrating real-time GTFS data and modular weight updating strengthens the adaptability of the model. Furthermore, while a formal sensitivity analysis was conducted to evaluate the impact of weighting changes specifically the age criterion. The output shows TAI distribution remained robust, affirming the model's internal stability. Site verification confirmed the alignment between predicted high and low TAI zones and real-world transit conditions, further reinforcing the model's external validity.

Another contribution, this research advances the discourse on accessibility modelling in low-transit, suburban environments by offering a context-sensitive, empirically validated decision-support tool. It also responds to growing scholarly calls for equity-centred transit planning, by explicitly incorporating population age, income, and density variables alongside infrastructure and service indicators.

In conclusion, the FAHP-GIS model developed for Puncak Alam not only delineates areas of transit advantage and disadvantage but also provides actionable insights for urban planners and policymakers. Its application in planning frameworks such as Rancangan Tempatan and the Selangor State Transport Master Plan can inform the allocation of feeder services, the siting of DRT, and the prioritization of TOD. Future research should expand the expert panel to enable judgment aggregation, test the model's transferability to other suburban regions, and integrate real-time service data to support dynamic transit accessibility monitoring. Ultimately, the TAI framework offers a scalable, inclusive, and adaptable approach to guiding sustainable transit investments in Malaysia and comparable suburban contexts globally.

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