Assessing Public Transport Accessibility through the PTQC System: The L'Aquila Case Study

Martin Grabner[1)], Gino D'Ovidio[2)]

[1)] Technical University of Vienna, Institute of Spatial Planning, Karlsplatz 13, 1040 Vienna, Austria, grabner.martin@outlook.de; ORCID 0009-0001-6113-2424
[2)] University of L'Aquila, DICEAA, Piazzale Pontieri 1, Monteluco di Roio, 67100 L'Aquila, Italy, gino.dovidio@univaq.it; ORCID 0000-0003-3978-604X

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Abstract

Assessing public transport accessibility is vital for urban and regional planning. This paper examines the enhanced Austrian Public Transport Quality Classes (PTQCs) system, a standardized framework inspired by Swiss models, that assesses accessibility by integrating service frequency, transport network hierarchy, and pedestrian connectivity. The system classifies areas into seven quality levels from high-accessibility urban zones to minimally served peripheries. The study applies the enhanced PTQCs framework to L'Aquila, a central Italian city characterized by a complex topography, historical layout, and ongoing post-earthquake reconstruction. Using GIS tools, the analysis involved data collection, adaptation of criteria, and spatial evaluation. Results highlight disparities: while central corridors meet quality standards, peripheral and rebuilt districts suffer from limited service and connectivity. The analysis also adopted a comparative approach, with the Austrian city of St. Pölten and its surrounding area serving as a reference due to their comparable population and territorial size. The comparison highlighted L'Aquila's functional gaps and confirmed the PTQCs system's adaptability across different urban contexts. The study highlights the need for better intermodality and real-time data integration to address evolving transport demands. Its findings offer useful insights for policymakers and planners aiming to enhance public transport while promoting equity, growth, and sustainability.

Keywords: *Public transport accessibility, GIS analysis, PTQC system, public transport quality*

1. Introduction

Public transport accessibility plays a fundamental role in shaping urban mobility, influencing individuals' ability to travel efficiently and participate in economic, educational, and social activities. A well-designed transport system enhances access to key destinations, such as workplaces, schools, healthcare facilities, and commercial centres, while also reducing car dependency and promoting sustainability [1, 2]. However, accessibility is not uniform across urban areas, as differences in infrastructure, transport network design, and socio-economic conditions create disparities that impact mobility. These variations particularly affect vulnerable populations, including low-income individuals, older adults, and those with disabilities, leading to limited travel opportunities and increased social inequality [3]. Ensuring equitable public transport accessibility is essential for fostering inclusive cities and enhancing urban resilience.

Measuring accessibility is a crucial step in identifying deficiencies in transport systems and informing policy decisions aimed at improving mobility. Different methodologies have been developed to evaluate accessibility, ranging from basic distance-based approaches [4] to more comprehensive models that incorporate land use, multimodal transport options, and sociodemographic characteristics [5]. While traditional indicators such as travel time and service coverage offer a general overview of accessibility, more advanced methods—such as GIS-based network analysis and gravity models—provide deeper insights by incorporating factors like service frequency, travel barriers, and network efficiency [1]. The increasing use of real-time transport data has further improved accessibility assessments by enabling the analysis of service reliability, congestion patterns, and actual travel behaviour [6]. Additionally, integrating accessibility analysis with sustainability objectives ensures that transport planning aligns with economic and environmental priorities [7].

A structured framework for accessibility assessment is the Public Transport Quality Classes (PTQCs) system, developed in Austria and based on methodologies used in Switzerland. This system evaluates public transport accessibility by examining key factors such as service frequency, network structure, and pedestrian access to transit stops. It categorizes areas into seven levels, providing a standardized method for comparing accessibility across different urban contexts and supporting infrastructure planning. Despite its effectiveness, accessibility challenges remain, particularly in suburban and rural areas where lower service frequency and weak intermodal connections limit mobility. Addressing these issues requires integrated solutions such as improving last-mile connectivity, expanding park-and-ride facilities, and adopting flexible mobility options like Mobility-as-a-Service (MaaS). These approaches aim to create more user-friendly and adaptable public transport systems.

To evaluate the suitability of the enhanced PTQCs system, it was applied to the city of L'Aquila, situated in central Italy and marked by unique mobility-related issues. L'Aquila's transport infrastructure is strongly influenced by its mountainous topography, the constraints of its historic urban fabric, and the complex dynamics of post-earthquake reconstruction, which continue to impact mobility patterns and planning efforts.

The study involved collecting transport data, adapting classification criteria to fit local conditions, and conducting spatial analysis using GIS tools. In light of the city's evolving urban landscape, the application of the PTQCS framework enabled a detailed assessment of accessibility strengths and gaps, offering valuable insights into how public transport services could be more effectively tailored to local needs.

The analysis also adopted a comparative approach, with the Austrian city of St. Pölten and its surrounding area serving as a reference due to their comparable population and territorial size.

By assessing the PTQCS system's adaptability to diverse urban conditions, this research contributes to the broader discussion on public transport accessibility and its role in urban mobility planning. By integrating spatial analysis with socioeconomic considerations, the study aims to offer a framework for designing transport networks that are more inclusive, efficient, and sustainable.

The article is organized as follows. Section II outlines the methodological approach, based on a redefined PTQCS system tailored to this study. Section III details its application to the city of L'Aquila, serving as the case study. Section IV presents the results through a comparative analysis, with the Austrian city of St. Pölten used as a benchmark. Concluding remarks are offered in the final section.

2. Methodology

The proposed methodology for assessing public transport accessibility is based on a structured classification system that integrates service quality, network coverage, and pedestrian accessibility. This approach, inspired by the Austria-wide Public Transport Quality Classes (PTQCS) system, provides a standardized framework for evaluating public transport access in diverse geographical contexts [8].

The methodology is grounded in five core principles to ensure a detailed differentiation between urban and rural areas. First, it establishes distinct public transport quality classes that consider spatial characteristics, ensuring appropriate differentiation in both densely populated urban centres and sparsely populated rural regions. Second, it categorizes transport services into four hierarchical levels, accounting for travel speed, capacity, comfort, and schedule reliability. The third principle involves weighting the significance of different transport categories based on spatial context, allowing for nuanced evaluations in different settlement structures. The fourth principle integrates walkability and service intervals into the assessment, recognizing the importance of walking distances to transit stops and the frequency of departures in determining overall accessibility. Finally, the fifth principle ensures that quality classifications are based on weekday public transport services, excluding variations caused by seasonal or exceptional Stop Categorization and Interval.

The PTQCS links the service quality of stops to their walkable accessibility, enabling a spatial assessment of public transport across different areas. Combined with demographic data, they offer valuable insights into potential demand, making the system a strategic tool for urban planning and for aligning transport services with land use development.

The framework includes seven quality classes, from A to G, each contextualized based on the spatial setting. Class A indicates the highest accessibility in urban areas; Class C reflects excellent access in peri-urban zones; Class E denotes basic but reliable access in rural areas; and Class G represents minimal service availability in remote rural contexts. The approach is described below, following the enhanced methodology proposed by ÖROK [8].

2.1 Stop categorization

The classification of stops is based on two main factors: the frequency of departures at a stop and the specific stop types considered for these intervals.

The analysis period spans from 6 a.m. to 8 p.m., covering a total of 840 minutes. It considers two types of weekdays: one with school operations and one without. The departure intervals are determined by summing the total departures of all transport modes and categories. This sum is then adjusted using a directional factor of 0.5, which applies universally, including to circular routes.

To calculate the average departure interval (I_a) over the reference period, the total duration is divided by the number of departures in each direction, following the methodology established by the Austrian Conference on Spatial Planning [8]. The calculation is performed using the following formula (1):

$$I_a = \frac{H \cdot 60}{f \cdot \sum_{i=1}^{n} D_i} \tag{1}$$

where: $\sum_{i=1}^{n} \boldsymbol{D_i}$ represents the total number of departures, H is the number of observed hours (e.g., from 6 a.m. to 8 p.m., $H = 14$), and f is the directional factor, set to 0,5 for unidirectional and bidirectional service.

Stops are assigned to different categories based on their interval class and the highest available transport mode, ensuring a hierarchy that distinguishes between long-distance rail services, metro, trams, express buses, and local buses. The classification allows for a more accurate reflection of service quality and ensures consistency in accessibility evaluation.

Therefore, according to the ÖROK method, interval classes are defined, as shown in Fig. 1.

Average interval between departures per direction	The transport mode category of the stop according to the highest-ranking mode of transport			
	Long-distance travel	Suburban Train / Metro, Regional Train, Express Bus, Local Train	Tram, Metro Bus, Trolleybus	Bus
< 5 min	I	I	II	III
5 - 10 min	I	II	III	III
10 - 20 min	II	III	IV	IV
20 - 40 min	III	IV	V	V
40 - 60 min	IV	V	VI	VI
60 - 120 min	V	VI	VII	VII
120 - 210 min		VII	VIII	VIII
> 210 min				

Fig. 1. Overview of the stop classes reference (Illustration by the authors based on ÖROK [8])

2.2 Public Transport Quality Classes

The final classification of public transport quality is based on two primary factors:

a) Walking distance to transit stops, which defines distance categories ranging from 0 to 1250 meters

b) Stop categories, which determine the service level at each stop based on transport modes and frequency.

The interaction between these factors allows for the classification of areas into seven public transport quality classes (A-G). Higher-ranking classes (A-C) correspond to areas with frequent, multimodal services, while lower classes (E-G) represent regions with basic access, typically in rural areas with less frequent services.

2.3 Spatial analysis

To support large-scale accessibility assessments, the classification system is integrated into Geographic Information Systems (GIS), such as ArcGIS and QGIS. This allows the calculation and visualization of public transport quality across 100-meter grid cells or polygons. The process of classification involves the following steps:

1) Mapping of transit stops and their service intervals to identify the distribution of transport services.
2) Calculation of walking distances to evaluate pedestrian access to public transportation options.
3) Assignment of public transport quality classes to both urban and rural regions, based on the combined impact of transport frequency and walkability.
4) Integration with demographic and land-use data, which helps assess transport demand and supports urban planning initiatives.

By linking transportation access to demographic information, this approach provides an effective tool for spatial planning, enabling evidence-based decisions in managing urban mobility.

2.4 Stop Categorization

Stop types are classified based on the categories of public transport services available at each location, following the ÖROK method. The mode of transport with the highest position in the network hierarchy defines the stop type. For instance, a stop served by both long-distance rail and local bus services is categorized as a long-distance stop; however, both modes are considered when calculating the departure interval.

There are four main stop types, as illustrated in Fig. 1. The highest category includes long-distance travel and regional express trains, followed by suburban trains, metro, regional trains, express buses, and local trains. The third category consists of trams, metro buses, and trolleybuses, while the lowest category comprises regular buses [8].

Stop categories are determined by combining interval classes with stop types. A total of eight stop categories (I–VIII) were introduced to reflect variations in service quality based on frequency and the highest transport mode available. Additionally, bus stop classifications differ between urban and rural areas. In both settings, the role of buses was evaluated about trams and metro buses, particularly those operating at intervals of 5–10 minutes or more [8].

The transport categories are based on predefined modes of transport, though some inconsistencies exist in differentiating between specific categories (e.g., regional express train vs. regional train, or bus vs. express bus). The final classification was established in coordination with regional authorities. For instance, in Styria, regional express train stations were classified as suburban train stations [8].

The public transport quality classification system applies exclusively to stops within walking distance and does not include Bike & Ride or Park & Ride facilities, as these are located farther from stops.

2.5 Public Transport Quality Classes

The establishment of quality classes occurs in two stages. The first stage involves defining distance categories based on the walking distance to the stop. In contrast, the second stage consists of assigning stop categories to these distance classes, resulting in the final public transportation quality class.

The walking distance classes were based on existing models, except the 1001–1250 meter category, which was added to account for stops with higher-ranking transport categories or greater interval density. Seven quality classes, ranging from A to G, were established in total, as shown in Fig. 2.

Category of the stop	Distance to the stop				
	≤ 300 m	301 – 500 m	500 – 750 m	751 – 1.000 m	1.001 – 1.250 m
I	A	A	B	C	D
II	A	B	C	D	E
III	B	C	D	E	F
IV	C	D	E	F	G
V	D	E	F	G	G
VI	E	F	G		
VII	F	G	G		
VIII	G	G			

Fig. 2. Overview of the distance classes (Illustration by the authors based on ÖROK [8])

The system can be represented in geoinformation systems (e.g., ArcGIS or QGIS) using 100-meter grid cells or polygons. By combining this with the Geoland Basemap, the existing settlement patterns can be linked to public transport quality classes, as well as zoning plans or spatial planning strategies. In the raster cell display, a cell is assigned to the public transport quality class that occupies the largest portion of the area, provided that this portion is at least 50%. If no class occupies more than 50% of the cell, the cell remains unclassified [8].

3. Case Study of L'Aquila City

As a case study for the proposed method, the city of L'Aquila was selected. Located in central Italy within the Abruzzo region and set amidst the Apennine Mountains, L'Aquila presents a complex territorial context, combining a historic urban core with a fragmented, mountainous landscape.

The 2009 earthquake deeply affected the city's spatial and functional organization. A major outcome was the displacement of residents from the historic center to newly built housing developments on the outskirts. This shift led to a decentralization of the population, reducing the centrality of the old town and fragmenting the urban structure. As a result, the public transport system - originally structured around a

compact, centralized network - became less effective. The increased dispersion of residences, coupled with low-density urban expansion, compromised service efficiency by lengthening travel distances, lowering demand concentration, and limiting accessibility, especially in peripheral zones.

Several methodological contributions have been proposed for the optimal reorganization of L'Aquila's public transport system; however, most of these have not yet been implemented in the current mobility framework [9, 10]. Additionally, recent analyses have addressed walkability within the urban context [11].

3.1 Methodological adaptations

The L'Aquila case study required a customized approach, with multiple adjustments necessitated by the scarcity and poor quality of available geospatial data.

Since no usable open-source information on bus stops was available, a custom georeferenced dataset was developed. Each stop was linked to the corresponding transport lines, and average headways were calculated based on the official service data provided in the timetables of the local public transport operator, AMA SpA L'Aquila [12]. Stops served by lines with average intervals over 210 minutes were excluded, resulting in a final dataset of 109 stops.

Two key methodological adaptations were introduced, with calculations performed both with and without them. The first concerned the classification of stops. Under the Austrian model, most bus stops in L'Aquila would fall into Category 4, limiting the assignment of higher PTQCs such as Class A. Since buses represent the dominant mode of transport—aside from two exceptions (line C, an express bus, and a regional train)—bus routes were reclassified as express services, upgrading their stop category from 4 to 2.

The second adaptation addressed the high average interval times, which often placed stops in the lowest PTQCs (Class VI–VIII) or excluded them entirely. To reflect peak-hour conditions, the observation window was reduced from the original 14 hours (6 a.m.–8 p.m.) to a two-hour morning period (8–10 a.m.), when service frequency is typically higher.

These adjustments aimed to make the PTQCs framework more responsive to local conditions and more relevant for spatial and mobility planning in L'Aquila. Without them, the Austrian system would classify nearly two-thirds of the population in PTQCs F or below, and one-third as lacking any access to public transport. The adaptations lowered the threshold for higher PTQCs and introduced greater differentiation, enhancing the system's value for local planning efforts.

3.2 Workflow overview

The first step was the creation of the stops, due to the lack of publicly available data, as a point feature with the stop location. Key parameters for each stop—such as the number of lines serving it and the total number of departures and arrivals—were assigned using data from the official timetables of public transport services provided by AMA SpA L'Aquila [12].

The average interval time (I_a) was calculated using formula (1), assuming:

$\sum_{i=1}^{n} \boldsymbol{D_i}$ as the total number of departures between 8:00 and 10:00 a.m., and

$H = 2$, corresponding to the two-hour observation period.

Based on the resulting I_a values, each stop was subsequently assigned to a quality category ranging from I to VIII, as illustrated in Fig. 3, in accordance with ESRI [13, 14]

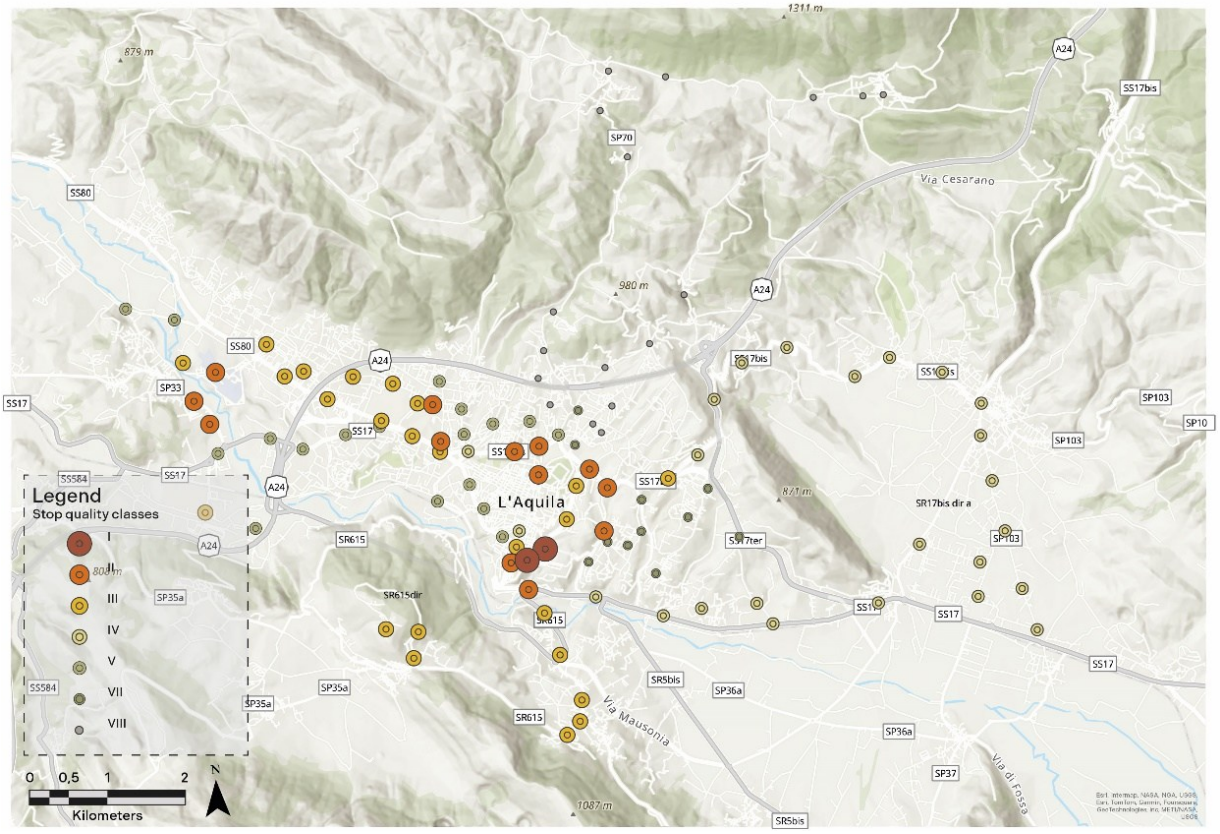

Fig. 3. Categorization of Stops in L'Aquila

The next step involved calculating walking distances to transit stops using data from OpenStreetMap Contributors [15], including all foot-accessible pathways. Distance categories range from a minimum of 0–300 meters to a maximum of 1000–1250 meters. Areas beyond this threshold are either excluded or considered not served by public transport.

Finally, these distance classes were mapped to the PTQCs. For instance, PTQCS A includes areas within 500 meters of Category I stops and within 300 meters of Category II stops.

To provide meaningful insights into the population distribution across the different PTQCs, the accessibility data was combined with resident population statistics. Data from the Istituto Nazionale di Statistica [16] was intersected with the PTQCS map and aggregated according to the respective quality classes.

Figure 4 presents the distribution PTQCs in L'Aquila. It is important to note that, on their own, PTQCs offer limited insight into the actual situation; meaningful conclusions can only be drawn when combined with additional data, such as resident population figures. The map highlights a concentration of high-quality classes along a few main arteries in the city center, as well as strong connections to the northern outskirts and a primary axis extending westward.

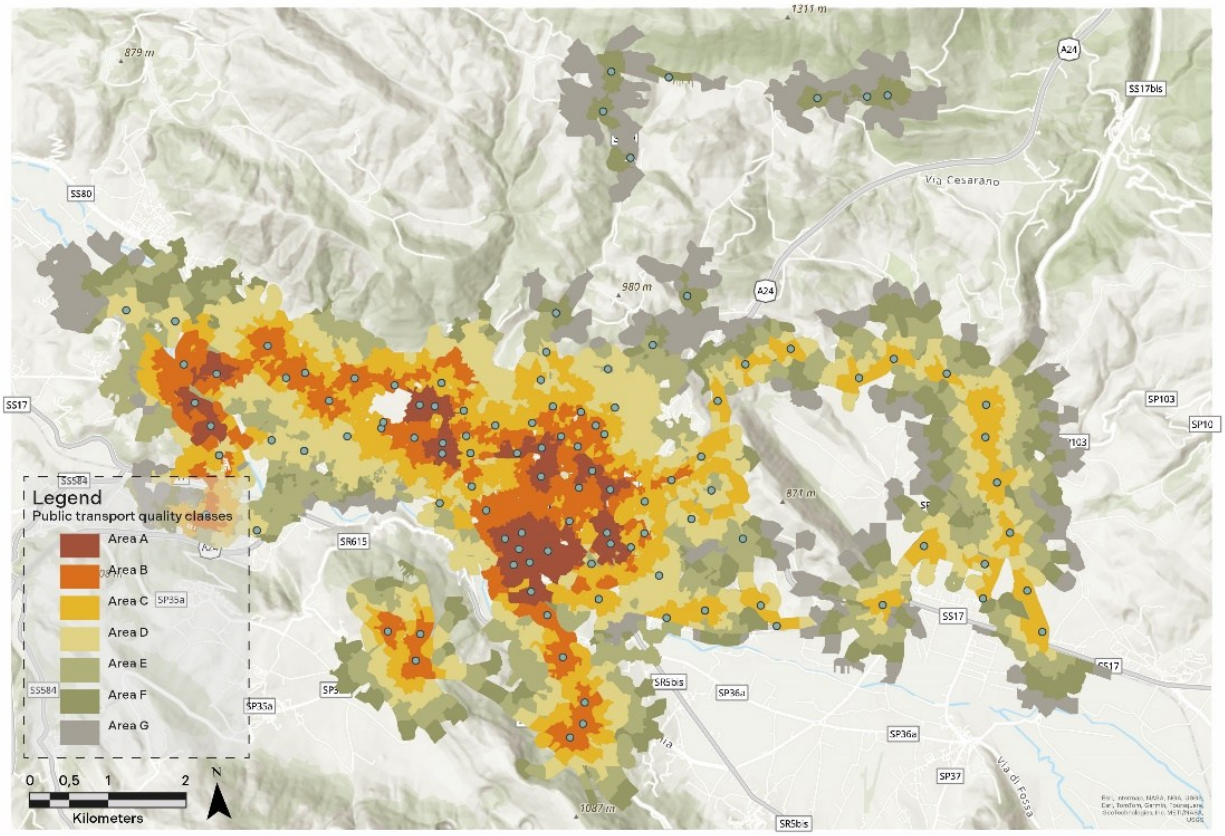

Fig. 4. Result of the PTQCs in L'Aquila

This pattern is primarily driven by the high-frequency bus lines serving the university campuses of Roio (to the south) and Coppito, along with the nearby industrial area to the west. The distribution of quality classes also reflects the underlying structure of the public transport network, which follows a radial configuration: routes converge from the outskirts toward a central point—namely, the Collemaggio bus terminal—or, due to the city's topography, to a narrowly defined inner-city area through which all external lines are channeled [17]. Figure 4 also highlights certain bus route extensions, particularly in the northern and eastern sectors, where coverage is limited and associated with lower PTQCs. These areas are characterized by sparse pedestrian infrastructure and limited accessibility, further exacerbated by incomplete or imprecise footpath data, leading to higher interval times and, consequently, lower-quality classifications.

4. Comparative analysis

A comparative analysis with the Austrian city of St. Pölten was conducted to aid in interpreting the results in the following phase.

While acknowledging the inherent differences between the political, social, and planning frameworks of Austria and Italy, the comparison aims to provide a reference point by focusing on areas with similar structural characteristics.

St. Pölten was chosen due to several socio-geographic similarities with L'Aquila. In terms of population, L'Aquila has 70,967 inhabitants [18], while St. Pölten counts 58,856 residents [19], making them broadly comparable. Both cities serve as regional capitals - L'Aquila for Abruzzo and St. Pölten for Lower Austria - implying similar administrative roles and functions, including their impact on public transport systems. Additionally, both are located relatively close to their national capitals and can be reached by car in approximately 1.5 hours.

The main difference lies in the size of their territories: L'Aquila spans roughly 470 km², nearly five times larger than St. Pölten (about 110 km²). However, since L'Aquila's population is concentrated in the urban core, the larger area has limited impact on accessibility calculations. To ensure a more meaningful comparison, St. Pölten was considered together with seven surrounding municipalities (Böheimkirchen, Herzogenburg, Karlstetten, Obritzberg-Rust, Pyhra, St. Veit an der Gölsen, and Wilhelmsburg), bringing the total population to 90,556 and the total area to 460.49 km² [19, 20]. This results in a population density of 196 inhabitants/km² for the St. Pölten region and 150 inhabitants/km² for L'Aquila.

The left two bars in the chart represent the results for L'Aquila, with and without the adaptations described in Section 3.1, while the right two bars show the results for St. Pölten—first for the city alone, then including its surrounding municipalities.

In L'Aquila, the adaptations lead to a clear improvement in public transport accessibility, particularly in PTQCs A to C, which show absolute increases between 5% and 11%. The proportion of the population with at least good accessibility (PTQCs A to D) rises to 50% with adaptations, compared to just 15% without. However, the proportion of residents without any access to public transport remains nearly unchanged: 31% without adaptations compared to 33% with.

For St. Pölten, the inclusion of surrounding municipalities has a predictable effect: while the city alone shows a concentration in higher PTQCs (A–D), the expanded area displays a more balanced distribution across all classes. Nonetheless, higher-quality levels remain relatively dominant, indicating a consistently accessible network beyond the urban core.

A direct comparison between the two cities highlights substantial differences. In L'Aquila, the centralized network results in a concentration of PTQCs B and C in the city center and main corridors. However, accessibility declines rapidly in peripheral areas due to low service frequency and sparse coverage. Without adaptations, this pattern persists, though population shares shift toward lower PTQCs. Notably, the share of residents without access to public transport is five times higher in L'Aquila than in St. Pölten.

In contrast, St. Pölten and its surrounding region show a more homogeneous accessibility profile, with PTQCS distributions ranging from 11% to 23% - excluding Class A and the no-access group. Despite reduced frequency in outer areas, public transport remains available across the region.

Overall, the analysis confirms that L'Aquila's public transport system is significantly less effective than its Austrian counterpart. Nearly 80% of its population lives in areas falling into rural-level accessibility (PTQCs E or lower), a performance that would not meet the standards expected for a city of its size, structure, and regional role under the Austrian classification model.

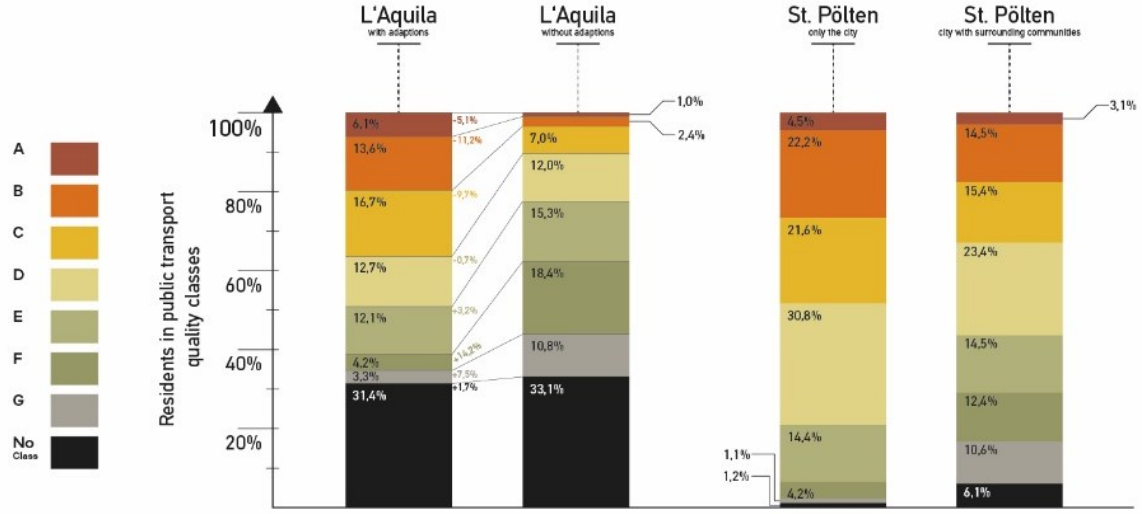

Fig. 5. Comparison of PTQCs distribution among residents in L'Aquila and St. Pölten

5. Conclusion

This paper applied the Austrian Public Transport Quality Classes (PTQCS) system to the city of L'Aquila (Italy), adapting the methodology to local conditions and assessing its effectiveness through both spatial analysis and comparative evaluation with the Austrian city of St. Pölten. The study provided insights into the accessibility of public transport in a L'Aquila post-earthquake urban context, highlighting critical gaps and the potential for targeted improvements.

Rather than interpreting the results through a binary lens of success or failure, they should be viewed as a foundation for informed spatial and mobility planning. While L'Aquila exhibits generally lower accessibility levels compared to St. Pölten, this outcome must be contextualized, as it does not fully reflect the influence of broader social, political, and economic dynamics.

The results of the analysis revealed substantial shortcomings in L'Aquila's public transport system: nearly 80% of residents live in areas classified as having rural-level accessibility (PTQCs E or lower). Additionally, approximately one-third of the population lacks any access to public transport, highlighting the urgency of targeted planning interventions.

Such a service level is inadequate for a city of this scale, urban morphology, and regional significance, particularly when evaluated according to the Austrian classification framework

Beyond land-use planning, continuous evaluation and adaptation of the public transport network are essential. The findings indicate that many opportunities to improve accessibility in L'Aquila remain underexploited. Forward-looking network planning can help close these gaps and better align transport services with the city's evolving spatial structure.

Findings from the study can inform strategies aimed at strengthening public transport, while advancing goals of social inclusion, sustainable growth, and balanced urban development.

References

1. K. T. Geurs and B. van Wee, Accessibility evaluation of land-use and transport strategies: Review and research directions, Journal of Transport Geography 12(2), 127–140 (2004).
2. T. Litman, Evaluating accessibility for transportation planning (Victoria Transport Policy Institute, Victoria, 2017).
3. K. Lucas, Transport and social exclusion: Where are we now?, Transport Policy 20, 105–113 (2012).
4. W. G. Hansen, How accessibility shapes land use, Journal of the American Institute of Planners 25(2), 73–76 (1959).
5. E. Papa et al., Accessibility instruments for planning practice: A review of European experiences, Journal of Transport and Land Use 9(3), 57–75 (2016).
6. T. L. Lei and R. L. Church, Mapping transit-based access: Integrating GIS, routes, and schedules, International Journal of Geographical Information Science 24(2), 283–304 (2010).
7. S. Nocera and F. Cavallaro, The economic impact of transportation sustainability: A strategic evaluation tool, Transport Policy 18(2), 453–463 (2011).
8. ÖROK - Österreichische Raumordnungskonferenz, Die Österreichweiten ÖV-Güteklassen: Rahmen, Struktur & Beispiele (Österreichische Raumordnungskonferenz, Wien, 2022).
9. G. D'Ovidio, D. Di Ludovico, and G. L. La Rocca, Urban Planning and Mobility Critical Issues in Post-Earthquake Configuration: L'Aquila City Case Study, Procedia Engineering 161, 1815–1819 (2016).
10. D. Di Ludovico, G. D'Ovidio, and D. Santilli, Post-earthquake reconstruction as an opportunity for a sustainable reorganisation of transport and urban structure, Cities 96, 102447 (2020).
11. F. Eugeni et al., Walkability Infrastructures and Urban Rebalancing: The Case Study of L'Aquila City under Post-Earthquake Reconstruction, Infrastructures 9(3), 42 (2024).
12. AMA SpA L'AQUILA, Elenco linee AMA, 2024 [Online]. Available: https://www.ama.laquila.it/linee-e-orari/elenco-linee-ama/. [Accessed: 03-Jun-2024].
13. Esri. "Topographic" [basemap]. Scale Not Given. "World Topographic Map". April 25, 2020. [Online]. Available: https://www.arcgis.com/home/item.html?id=30e5fe3149c34df1ba922e6f5bbf808f. (Accessed: 03-Jun-2024).
14. Esri. "World Hillshade" [basemap]. Scale Not Given. "World Hillshade Map". April 25, 2020. [Online]. Available: https://www.arcgis.com/home/item.html?id=7dc6cea0b1764a1f9af2e679f642f0f5. (Accessed: 3-Jun-2024).
15. OpenStreetMap Contributors, OpenStreetMap Export, 2024. [Online]. Available: https://www.openstreetmap.org. [Accessed: 03-May-2024].
16. Istituto Nazionale di Statistica, Basi territoriali e variabili censuarie, 2011. [Online]. Available: https://www.istat.it/notizia/basi-territoriali-e-variabili-censuarie/#accordions. [Accessed: 03-May-2024].
17. U. Köhler, Einführung in die Verkehrsplanung: Grundlagen, Modellbildung, Verkehrsprognosen, Verkehrsnetze (Fraunhofer IRB Verlag, Stuttgart, 2014).
18. AdminStat, Mappe, analisi e statistiche sulla popolazione residente, 2022. [Online]. Available: https://ugeo.urbistat.com/AdminStat/it/it/demografia/dati-sintesi/l-aquila/66049/4. [Accessed: 13-Mar-2025].
19. Statistik Austria, Ein Blick auf die Gemeinde, 2024. [Online]. Available: https://www.statistik.at/atlas/blick/. [Accessed: 13-Mar-2025].
20. A. Tseik, Gemeindeverzeichnis: Stand 1.1.2021 (Statistik Austria, Wien, 2021).