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High-Speed Rail and Accessibility. Quantitative Evidence from the Italian Context

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Introduction

- High-Speed Rail (HSR) infrastructure reshapes territorial accessibility by substantially reducing travel times between major destinations (Cavallaro et al., 2023). Such improvements extend beyond transport performance, influencing the **spatial organization** of urban areas and the **socioeconomic dynamics** of settlements located along or near HSR corridors (Gong & Li 2022; Zou et al., 2024).
- Furthermore, taking into strict consideration the huge investments and the economic, environmental, and social impacts associated with the several new HSR stations planned across Italy, an integrated and **comprehensive understanding** of their effects on accessibility, territorial equity, and local development is essential to support **informed planning and policy decisions**.

Literature background

Efficiency and Accessibility

- HSR significantly improves network efficiency by increasing accessibility and reducing **generalized travel times**, enhancing **cities' competitiveness** and **economic potential**, particularly in major urban areas (Cascetta et al., 2020).
- From current literature, it emerges **accessibility** to be the **key indicator** for evaluating **HSR impacts**, capturing both travel time reductions and access to opportunities. The largest accessibility gains are generally concentrated in cities directly served by HSR stations, while benefits for other areas depend on the quality of feeder transport connections (Cheng & Chen, 2022).

Spatial equity

- HSR appraisal should jointly consider efficiency and spatial equity, as maximizing efficiency alone may reinforce territorial disparities (Bruzzone et al., 2023).
- Spatial equity is assessed through the **distribution of accessibility improvements** across territories rather than their aggregate magnitude (Bruzzone et al., 2023).
- A geographically balanced HSR network can improve overall territorial equity, although some cities may continue to experience relatively limited benefits (Bruzzone et al., 2023).

Literature background

Research gap and objectives

- From current literature, it emerges a consistent gap, concerning the **fragmentation of HSR's impact understanding** that appears to be fundamental to fully exploit HSR's socio-economic and environmental benefits. *Ma et al., 2026*). Therefore, current knowledge lacks a comprehensive and integrated approach towards both efficiency and equity analysis of the entire Italian network.
- The present study aims to provide both scholars and practitioners with a **deeper understanding** concerning the **accessibility, efficiency** and **spatial equity implications** on Italian HSR system. Thus, the suggested framework would enable the Italian integrated transport network to efficiently manage available levers towards the several future HSR implementations.

Research sample

- **69 HSR stations** analysed across the Italian railway network;
- **48 non-HSR stations** analysed across the Italian railway network;
- **2008 and 2019** considered as reference years;
- Analysis conducted at **station level**, with aggregation at **regional level**;
- **Accessibility** measured for each station based on the time travel distance between **origin** and **destination**.

Comparison between 2008 and 2019 used to assess:

- **Accessibility levels**;
- **Changes** in accessibility;
- **Spatial equity**, through the Coefficient of Variation (CV);
- **2019** last comparable year for assessing the effects of HSR measures, since passenger traffic not yet stabilized by 2023 due to wars, pandemics, and energy prices' fluctuations.



Formula

Accessibility analysis

$$A_i = \sum_j \frac{P_j}{I_{ij}}$$

$$I_{ij} = TTF(E_i, E_j) + TTR(E_j, j) + \theta_F$$

i = Origin

j = Destination

P = Municipality population

I_{ij} = Generalized travel time from i to j

Efficiency analysis

$$AC_i = \frac{A_{i0} - A_{is}}{A_{i0}}$$

i = Origin

j = Destination

0 = 2008 HSR Network

S = 2019 HSR Network

Spatial Equity analysis

$$CV = \frac{\sigma^P_i}{\frac{\sum A_i * P_i}{\sum P_i}}$$

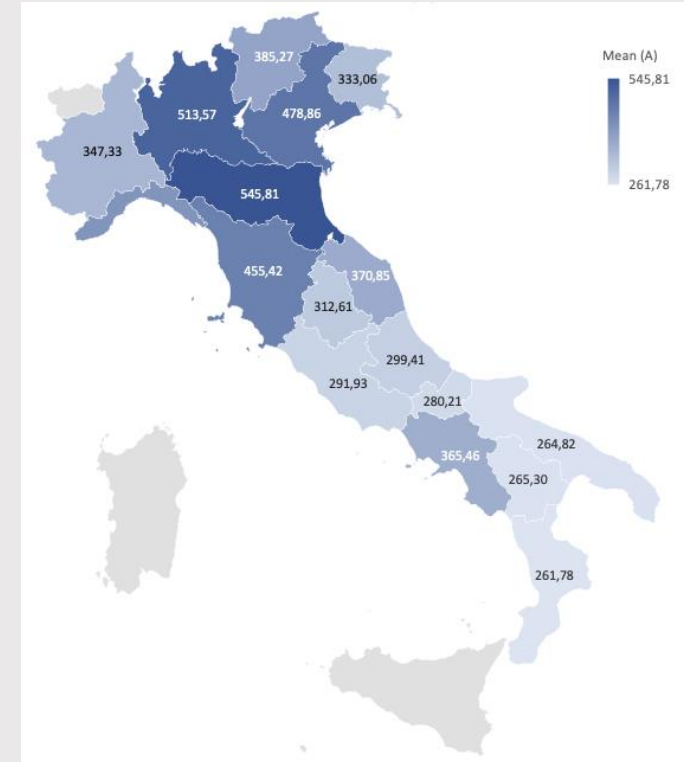
i = Origin

P = Municipality population

σ^P_i = Standard deviation of Accessibility

Accessibility 2008 | A clear North–South divide

- **National average:** 363.97
- **Above national average:** Emilia-Romagna, Lombardy, Veneto, Tuscany, Liguria, Trentino-Alto Adige
- **Relatively high but below average:** Piedmont, Friuli-Venezia Giulia
- **Lowest accessibility:** Calabria, Puglia, Basilicata
- **Most disadvantaged stations:** Ferrandina–Scalo Matera, Taranto, Lamezia Terme, Sibari, Reggio di Calabria, Brindisi, Lecce
- **Rome:** below the national average despite its strategic economic and institutional role



Accessibility 2008 | Unequal accessibility across the network



Accessibility 2008–2019 | Growth and spatial convergence

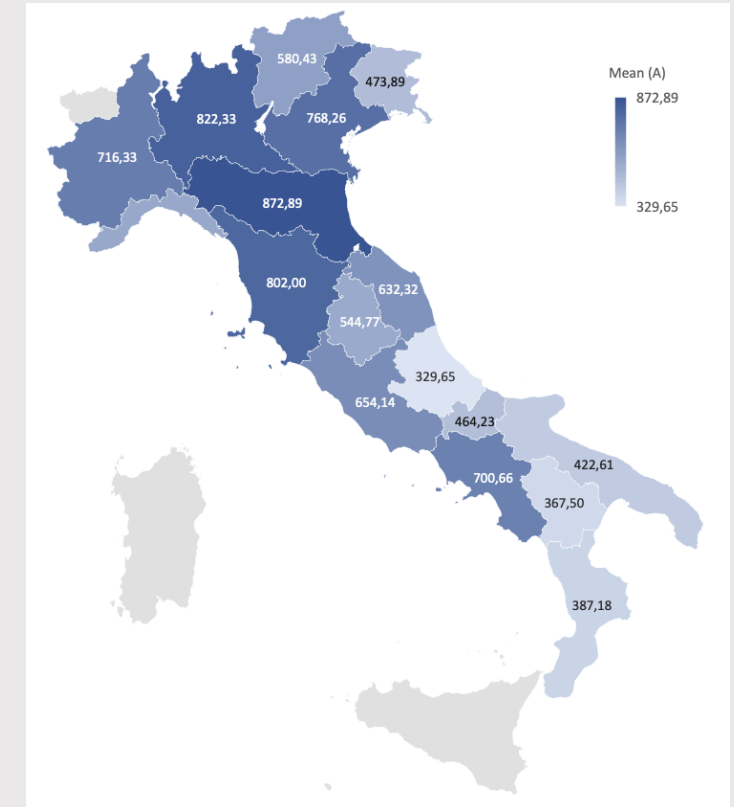
2008

- **National average:** 363.97
- Strong North–South divide
- Concentration of high accessibility in Northern regions
- Southern stations predominantly below average

+59,20%

2019

- **National average:** 593.57
- Higher overall accessibility
- Greater spatial homogeneity
- Previously disadvantaged regions showing above-average growth



Accessibility 2019 | Significant improvement in accessibility



Coefficient of Variation 2008–2019 | Unequal distribution of accessibility gains

↓ Spatial equity

Stations with increasing CV

Giulianova: +103.7%

Ancona: +81.5%

Naples: +~50%

Caserta: +~43%

Sibari: significant increase

↑ Spatial equity

Stations with decreasing CV

Ferrandina–Scalo Matera: –85.3%

Latisana Lignano-Bibione: –52.5%

Cervignano-Aquileia-Grado: –40.4%

Chiusi-Chianciano: –37.4%

Villa San Giovanni: –22.5%

- Despite the substantial increase in accessibility between 2008 and 2019, **spatial equity did not improve uniformly** across the HSR network, as the impacts varied considerably across northern, central, and southern Italy;

Final summary

- HSR investments have **improved accessibility and efficiency** across the **entire network**, with above-average growth in **Central and Southern regions**;
- Despite a general and relatively homogeneous increase in accessibility and efficiency during the reference timeframe, **spatial equity** shows an **overall decline**, suggesting that improved network performance does not necessarily translate into a more balanced distribution of benefits. Such may reflect localized **territorial rebalancing processes** and **differences** in **service quality and connectivity** among HSR stations.
- In contrast to past studies, the current research underlines the **absence** of **spatial polarization** as, from a regional point of view, HSR produces **heterogeneous spatial equity outcomes** across Italian regions.
- In conclusion, future HSR extensions should jointly consider **network efficiency and spatial equity**, also **strengthening connections** and the integration of HSR stations within transport networks.



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