A Transit-Oriented Development Evaluation Framework for County-Level High-Speed Rail Stations

Haoyun Sun *

School of Civil Engineering, Southwest Jiaotong University, 611756 Chengdu, China

* Corresponding Author Email: sunhaoyun@my.swjtu.edu.cn

Abstract. This thesis proposes a three-dimensional Transit-Oriented Development (TOD) evaluation framework applicable to county-level high-speed rail stations, taking into account transport node, place function, and development governance. Based on the characteristics of county-level high-speed rail stations, such as small scale, strong dependence on feeder connections, and constrained development pace, the framework helps identify shortcomings in station areas with respect to transport organization, functional configuration, and implementation foundations. Through case validation of four county-level station areas —Yangxin Station, Miluo East Station, Xianju Station, and Mile Station—the study finds that the framework can effectively identify the major problems of station areas and provide an operational basis for preliminary diagnosis and strategy formulation at the county scale under publicly available information conditions. This thesis argues that the development of county-level high-speed rail station areas should follow the principle of "first ensuring usable transport, then shaping the place, and finally upgrading functions," so as to improve the realism and sustainability of development.

Keywords: Transit-Oriented Development; county-level high-speed rail station; station area; evaluation framework; transport organization.

1. Introduction

High-speed rail stations not only undertake the function of interregional transport connectivity but have also gradually become important nodes for driving urban spatial restructuring and the spillover of public services. Transit-Oriented Development (TOD) emphasizes public transport stations as the core, and through compact development, mixed land use, and pedestrian-friendly spatial organization, seeks to achieve coordination between transportation and land use, thereby improving travel efficiency and spatial vitality [1]. In recent years, high-speed rail station areas have frequently been incorporated into the planning discourse of TOD or "station-city integration," yet existing studies have mostly focused on large-city hubs or urban rail transit stations, while research on county-level high-speed rail station areas remains relatively limited. Although the TOD concept has been widely introduced into the planning of high-speed rail station areas in China, in the context of small and medium-sized cities it is more likely to give rise to problems such as premature development, insufficient everyday functions, and separation between the station and the city [2]. At the same time, high-speed rail can promote the expansion of urban built-up areas and intensify land use, but such impacts are constrained by city size, locational conditions, and industrial foundations, showing marked heterogeneity [3,4]. High-speed rail station areas can to some extent stimulate commercial agglomeration, yet their performance is still affected by differences in station-area conditions [5]. In addition, research on "station-city integration" emphasizes that station development should not only focus on transport facilities themselves but should also pay attention to the coordinated relationship between station areas and urban functions, public services, and spatial organization [6]. Against this background, county-level high-speed rail station areas cannot simply replicate the experience of large cities; instead, they should be assessed according to their own passenger flow base, station-city relationship, and development capacity. On this basis, this thesis focuses on county-level high-speed rail stations and attempts to construct an evaluation framework that considers transport nodes, place functions, and development governance, and tests its applicability through case comparison. Under conditions of strong resource constraints and uncertain demand growth, this study explores how

county-level high-speed rail station areas can identify their principal shortcomings and thereby formulate more realistic development approaches.

2. Research approach

This thesis proceeds according to the logic of "problem identification—framework construction—case validation". As shown in Fig.1, first, on the basis of reviewing studies on TOD and high-speed rail station areas, and in light of the characteristics of county-level stations—such as smaller scale, stronger dependence on feeder connections, and more constrained development pace—it extracts the key factors affecting station-area development. Second, it constructs a three-dimensional Node–Place–Governance evaluation framework and establishes an A/B/C grading scheme to identify the major weaknesses of station areas in terms of transport organization, everyday functions, and implementation mechanisms. Finally, it selects the Yangxin County High-Speed Rail New Area and the Liuyang High-Speed Rail New Town area, for which relatively complete public information is available, for comparative analysis, so as to test the applicability of this framework at the county scale. The method emphasizes generating clear and verifiable diagnostic results under publicly available information conditions, thereby providing a basis for subsequent strategy formulation.

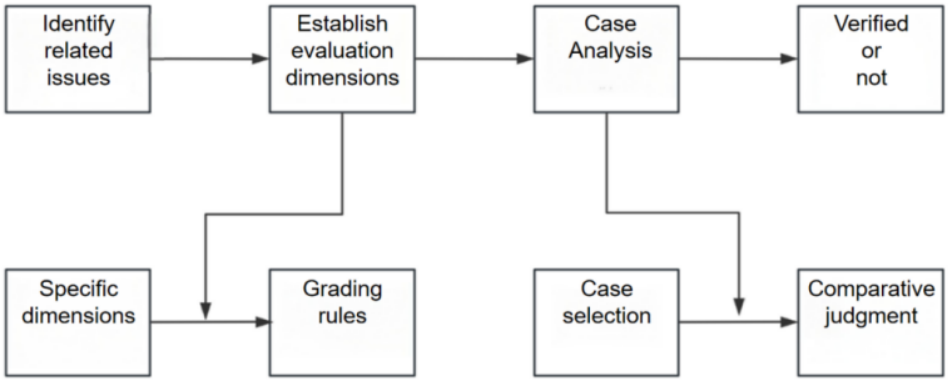


Fig 1. Research framework.
(Picture credit: Original).

3. TOD evaluation framework for county-level high-speed rail stations

To take into account both the transport attributes of high-speed rail stations and the development attributes of station-front areas, this thesis, as shown in Table 1, builds on node-place-related studies [7-9] and further introduces a governance dimension in light of the implementation characteristics of high-speed rail station areas, thereby forming a Node–Place–Governance evaluation framework. The Node dimension mainly examines accessibility between the urban area and the station, transfer organization, and last-mile feeder service provision, with a focus on evaluating "whether the station is convenient to reach and transfer within." The Place dimension mainly examines the completeness of everyday functions, walkability and public space, and the match between development intensity and demand, with a focus on evaluating "whether the station area supports everyday use and sustained vitality." The Governance dimension mainly examines phasing mechanisms, industrial introduction, and investment, financing, and operational arrangements, with a focus on evaluating "whether the plan has a viable basis for implementation." In the evaluation method, A indicates relatively strong conditions, B indicates that the basic conditions are present but still require improvement, and C indicates clear weakness. Existing studies on the node-place model have shown that this method can be used both to identify the degree of match between transport supply and place functions in station areas, and to classify stations in conjunction with spatial integration, accessibility, and passenger flow performance [10,11]. Studies by some Chinese scholars on improved and extended node-place models for urban rail transit TOD further demonstrate that this type of method has strong adaptability

in the localization of evaluation indicators and the identification of station types [12, 13]. Considering the limited availability of data for county-level stations, this thesis adopts a simplified grading method based mainly on public planning documents, road network information, and basic background data, with an emphasis on identifying combinations of weaknesses rather than constructing a strict statistical model.

Table 1. TOD evaluation indicator system for county-level high-speed rail stations.

Dimension	Code	Indicator	A (Strong)	B (Moderate)	C (Weak)
Node	N1	Urban area–station accessibility	Mainly 15–25 min, with stable routes	Mainly 25–40 min	>40 min or complex transfers
Node	N2	Transfer organization and order	Clear movement lines, few conflicts	Localized congestion/conflicts	Obvious conflicts, weak wayfinding
Node	N3	Last-mile feeder service provision	Feeder express routes / local circulator services relatively well developed	Available but low frequency	Basically, absent or unusable
Place	P1	Completeness of everyday functions	Everyday living services relatively complete	Some functions available	Mainly vacant land / image-oriented development
Place	P2	Walkability and public space	Continuously accessible and suitable for staying	Partial discontinuities	Obvious fragmentation, poor stay quality
Place	P3	Intensity and demand	Phased development with strong flexibility	Tendency toward premature development	Clearly premature / risk of vacancy
Governance	G1	Phasing and flexibility mechanisms	Clear stage objectives and adjustable	Phasing exists but weakly quantified	Rolled out all at once
Governance	G2	Feasibility of industrial introduction	Clear carriers/platforms and demand support	Broad direction only	Mere slogan / lacks concrete carriers
Governance	G3	Investment, financing, and operational arrangements	Clear mechanisms with cash-flow considerations	Partially clear	Lacks arrangements for sustained operation

Furthermore, in conjunction with existing studies on differences in TOD levels at high-speed rail stations and land-use changes around station areas [14, 15], this thesis offers a heuristic interpretation of county-level station areas, as shown in Fig.2: the greater the distance between the station and the city, and the more difficult the feeder access, the more the station area depends on transport reinforcement; the weaker the demand and industrial carrying capacity, the more development pace should be controlled to avoid vacancy risk.

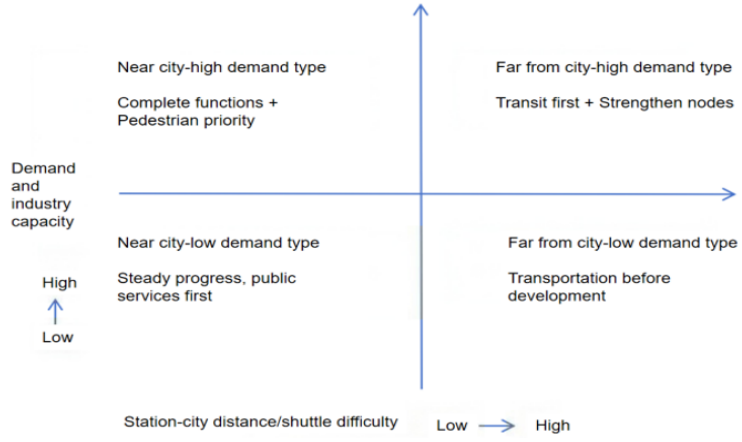


Fig 2. TOD typology of county-level high-speed rail stations. (Picture credit: Original).

4. Case validation

To verify the applicability of the above evaluation framework to county-level high-speed rail stations, this thesis selects four county-level high-speed rail station areas: Yangxin Station, Miluo East Station, Xianju Station, and Mile Station. The four samples differ in type, corresponding respectively to different development paths, including integrated new-area development, industry-city synergy orientation, transport-first cultivation, and composite functional introduction. They are therefore suitable for cross-case validation of the evaluation framework proposed in Section 3. Fig.3 schematically illustrates the basic characteristics of the four samples, focusing on the basic relationship among the "urban area—station—station-front district".

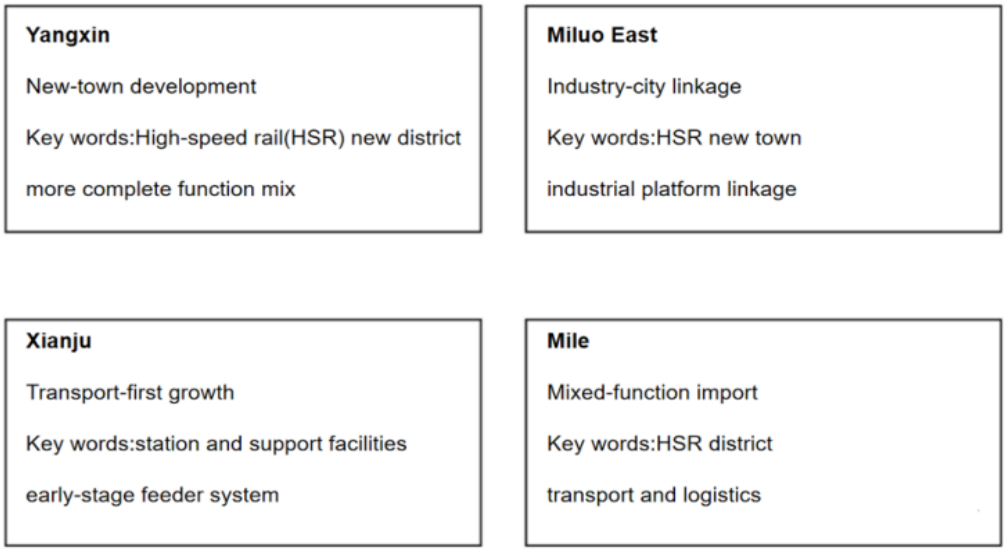


Fig 3. Basic characteristics of the four stations.
(Picture credit: Original).

Based on the evaluation framework proposed in Section 3, this thesis further assigns conservative grades to the four samples, as shown in Table 2. Overall, all four stations exhibit typical characteristics of county-level high-speed rail station areas: the Node dimension is generally moderate, while differences in the Place and Governance dimensions are more pronounced. Among them, Yangxin Station performs relatively well in the Place dimension and is more suitable for discussing functional structure and development pace; Miluo East Station is relatively balanced across all three dimensions and is more suitable for discussing coordination between the station and industrial platforms; Xianju Station is relatively weaker in the Place dimension and better reflects the issues of feeder connections and place cultivation in the initial stage of station-area development; Mile Station is relatively prominent in the Governance dimension and is more suitable for discussing industrial introduction and the organization of composite functions. Fig.4 presents a more intuitive comparison of the three-dimensional evaluation results across the stations in the form of a radar chart.

Table 2. Grading results.

Station	Node (N1/N2/N3)	Place (P1/P2/P3)	Governance (G1/G2/G3)	Type Characteristics
Yangxin Station	B/B/B	A/B/B	B/B/B	Structurally relatively complete type
Miluo East Station	B/B/B	B/B/B	B/B/B	Industry-city synergy type
Xianju Station	B/B/B	B/C/B	B/B/B	Transport-first type
Mile Station	B/B/B	B/B/B	B/A/B	Composite-introduction type

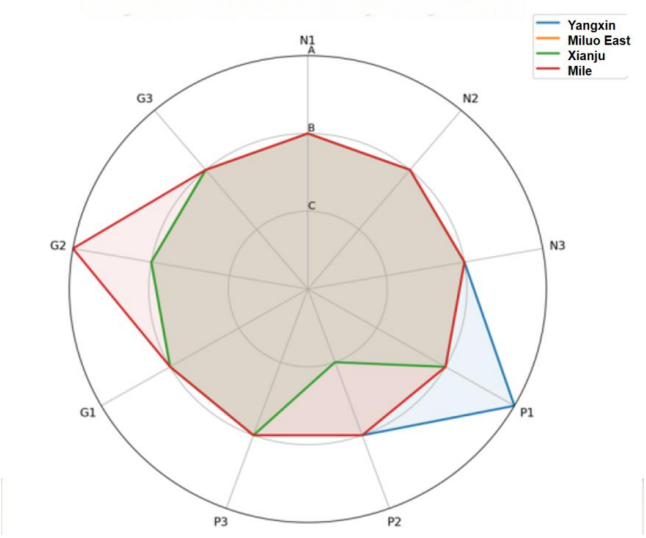


Fig 4. Comparison among stations.
(Picture credit: Original).

It can thus be seen that the evaluation framework proposed in Section 3 is capable of effectively identifying the differentiated weaknesses of county-level high-speed rail station areas in terms of transport, place, and governance, and supports preliminary diagnosis under multi-case conditions.

5. Conclusion

Overall, this thesis constructs a Node–Place–Governance evaluation framework and, based on publicly available information, conducts a preliminary grading assessment of county-level high-speed rail station areas. Through validation using four cases—Yangxin Station, Miluo East Station, Xianju Station, and Mile Station—it can be seen that the framework is able to identify differences among county-level high-speed rail station areas in transport, place, and governance, thereby providing a basis for subsequent strategy formulation. This research path of "framework construction—case validation—strategy induction" forms a relatively complete research loop.

The study shows that the key to TOD development for county-level high-speed rail stations does not lie in simply expanding the scale of new station-front areas, but rather in whether a basic matching relationship is formed among transport nodes, place functions, and governance mechanisms. Combined with the evaluation results of the four cases, the more common shortcomings in county-level high-speed rail station areas mainly fall into three categories: first, station-city feeder connections and transfer organization remain inadequate; second, the maturity of everyday services and public spaces in station-front areas is insufficient; and third, the linkage among development pace, industrial introduction, and operational arrangements remains unclear. By contrast, the Node dimension in county-level station areas often shows that the basic conditions are generally in place, while differences among station areas are more strongly reflected in the Place and Governance dimensions.

TOD development for county-level high-speed rail stations is better suited to following the basic path of "first ensuring usable transport, then shaping the place, and finally upgrading functions." For transport-first station areas, priority should be given to improving feeder bus services, local circulator routes, and station-front distribution and collection organization. For station areas with insufficient place cultivation, priority should be given to supplementing education, cultural and sports facilities, medical services, and convenience services, while improving the continuity of slow-traffic systems and the quality of public space. For station areas characterized by new-area development or composite functional introduction, emphasis should be placed on phased construction, rolling land supply, and the arrangement of operating entities, so as to reduce the risk of premature development and gradually promote a matching relationship among transport, place, and governance.

References

[1] A. Ibraeva, G.H. de A. Correia, C. Silva, A.P. Antunes, Transit-oriented development: A review of research achievements and challenges. Transp. Res. Part A Policy Pract. **132**, 110-130 (2020). https://doi.org/10.1016/J.TRA.2019.10.018

[2] B. Wang, M. de Jong, E. van Bueren, A. Ersoy, Y. Meng, Transit-oriented development in China: A comparative content analysis of the spatial plans of high-speed railway station areas. Land **12**, 1818 (2023). https: // doi.org/ 10.3390 / land12091818.

[3] P. Zhu, does high-speed rail stimulate urban land growth? Experience from China. Transp. Res. Part D Transp. Environ. **98**, 102974 (2021). https://doi.org/10.1016/J.TRD.2021.102974

[4] X. Li, X. Ma, Impacts of high-speed rail development on urban land expansion and utilization intensity in China. J. Transp. Land Use **14**, 583-601 (2021). https://doi.org/10.5198/JTLU.2021.1804

[5] P. Liang, X. Cui, M. Lin, T. Yang, B. Wu, High-speed rail effects on station area-level business commercial agglomeration: Evidence from 110 stations in China. Front. Environ. Sci. **10**, 1045959 (2022). https://doi.org/10.3389/fenvs.2022.1045959

[6] H. Sheng, Conceptual analysis and evaluation factors of station-city integration. Urban Transp. China **20** (3) (2022). https://doi.org/10.13813/j.cn11-5141/u.2022.0020

[7] W. Zheng, S. Wei, A node-place-network-city framework to examine HSR station area development dynamics: Station typologies and development strategies. J. Transp. Geogr. **120**, 103993 (2024). https://doi.org/10.1016/J.JTRANGEO.2024.103993

[8] L. Bertolini, Station areas as nodes and places in urban networks: An analytical tool and alternative development strategies, in Railway Development (Physica-Verlag HD, Heidelberg), (2008). https://doi.org/10.1007/978-3-7908-1972-4_3

[9] L. Lu, H. Deng, Progress and prospect of the node-place model and its application. Sci. Geogr. Sin. **39** (1), 12-21 (2019). https://doi.org/10.13249/j.cnki.sgs.2019.01.002

[10] S. Monajem, F. E. Nosratian, The evaluation of the spatial integration of station areas via the node-place model; an application to subway station areas in Tehran. Transp. Res. Part D Transp. Environ. **40**, 14-27 (2015). https: //doi.org/10.1016/J.TRD.2015.07.009.

[11] H. Wu, J. Lee, D. Levinson, The node-place model, accessibility, and station level transit ridership. J. Transp. Geogr. **113**, 103739 (2023). https://doi.org/10.1016/J.JTRANGEO.2023.103739

[12] Z. Zhang, S. Gao, Y. Chen, Z. Xiao, J. Deng, Q. Xu, Evaluation of urban rail transit TOD based on enhanced node-place model. Transport Res. **8** (3), 143-153 (2022). https://doi.org/10.16503/j.cnki.2095-9931.2022.03.015

[13] X. Lu, J. Wang, Z. Zhang, X. Hu, H. Guo, Evaluation and classification of Beijing rail microcenter subway stations based on extended node-place model. Sci. Technol. Rev. **41** (24), 41-51 (2023). https://doi.org/10.3981/j.issn.1000-7857.2023.24.006

[14] J. Deng, L. Cheng, C. Wu, T. Jin, F. Witlox, National-scale analysis of transit-oriented development levels at high-speed rail stations in China. Transportation (2025). https://doi.org/10.1007/s11116-025-10635-4

[15] F. Wenner, A. Thierstein, High-speed rail as urban generator? An analysis of land use changes around European stations. Eur. Plan. Stud. **30** (2), 227-250 (2022). https://doi.org/10.1080/09654313.2021.1946485