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A Study on the Rail Transit Economic Field and Its Interactive Development Relationship with Cities from the Temporal-Spatial Perspective

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Abstract: As metropolitan areas expand spatially, they encounter constraints imposed by the fixed daily time budget. Rail transit enhances transport efficiency, reduces costs, and facilitates the formation of a "transit economic field" centered on rail networks, thereby alleviating such temporal-spatial pressures. This paper adopts an integrated temporal-spatial analytical framework. Following a conceptual clarification of the transit economic field, it dissects the mechanisms through which rail transit improves mobility and examines how this field influences urban spatial patterns, temporal dynamics, and their interrelationships. It constructs a theoretical framework to explain the co-development of transit economic fields and cities, supplemented by empirical case studies. The key findings are as follows: Firstly, the transit economic field represents a high-density development model that expands both horizontally and vertically around rail networks. It mitigates temporal-spatial conflicts. Secondly, with rail networks as the core, the field integrates diverse spatial functions, facilitating the establishment of economic connections and stabilizing temporal-spatial relationships. Thirdly, the transit economic field contributes to the preservation of urban natural ecosystems and enhances urban livability. Overall, this research can provide insights for promoting rail transit-oriented development transitions in large cities and urban agglomerations.

Keywords: Rail transit; Rail transit economic field; Temporal-spatial relationship; Accessibility

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1. Introduction

Transportation serves as the fundamental guarantee for urban operation and a key factor that influences or even determines urban efficiency. Urban rail transit outperforms road-based transport modes in terms of speed, transport capacity, and stability, and has played a significant role in economic development and urbanization. For instance, the Tokyo Metropolitan Area in Japan has formed a high-density rail transit network consisting of JR railways, private railways, and urban subways, which underpins the high-density development of the core area of Tokyo and the radial expansion of peripheral areas around rail lines [1]. The Grand Paris region has established a rail network composed of central urban metro and suburban RER (Réseau Express Régional) rapid rail transit, meeting the commuting needs between the core area and peripheral new towns and promoting the development of a polycentric city [2]. Rail transit has not only become the backbone of transportation in developed metropolitan areas and urban agglomerations such as Tokyo, Hong Kong, China, Paris, and New York, but also a focus of transportation construction in major cities of many developing countries, including Bangkok, Bengaluru, and Curitiba [3].

Based on the service spatial scope, rail transit can be classified into different types, such as intercity trunk railways, suburban railways, and urban rail transit. Regardless of the type, rail transit features the characteristic of exclusive right-of-way, enabling closed and independent operation that is generally not affected by external environments. Existing development experiences have shown that rail transit is not only an effective transport mode but also exerts a significant impact on urban form, constructing an economic model of efficient development centered around rail networks.

In physics, the interaction between two objects is mediated by a "field." With one object as the center, a field refers to the spatial scope within which the object exerts influence on other surrounding objects, and the closer the distance, the stronger the influence. The field theory was later extended to fields such as psychology and sociology, which hold that individual or group behavior is not only influenced by preferences but also by the rules of the "field" they are in, thereby generating interactive relationships. Based on the above conceptual connotations, this paper defines the rail transit economic field as a development model and urban form centered on rail transit networks, with rail transit as the dominant travel mode, where population and resources agglomerate around stations and lines, and the agglomeration density gradually decreases from the center to the periphery. Why does the rail transit economic field form? How does it affect urban development? This paper will explore the above questions.

2. Literature review

Economics, geography, and other academic fields all acknowledge transportation as a key factor shaping land location patterns. From agricultural location theory and industrial location theory to transportation location theory, scholars have examined the relationship between transportation infrastructure—including ports and railways—and urban development. The Transportation Revolution explores the role of canals and railways in America's urbanization process [4]. Schivelbusch contended that railways not only transformed transportation modes but also reshaped human perceptions of time and space [5].

As urban spaces expand and populations grow, railways have begun to assume a role in intra-urban transportation, catering to substantial internal transportation demands. To accommodate the need for spatial expansion, regions have leveraged the advantages of railway transportation to guide outward population migration. The concept of Transit-Oriented Development (TOD), first proposed by Calthorpe, is grounded in the principle of coordinating transportation planning with land use to optimize urban form [6]. Bertolini proposed the Node-Place (N-P) Model, highlighting that areas surrounding rail transit stations possess the dual attributes of being both "nodes" and "places." Effective utilization of the node function can attract passenger flow to enhance the commercial value of the region, while rational development and utilization of the place function can boost passenger flow for rail transit [7]. The N-P Model is also frequently employed to assess the development status and potential of rail transit stations.

The TOD model for rail transit has seen numerous successful applications in densely populated metropolitan areas across Asia. In Tokyo's TOD development, private railway companies have played a pivotal role. Through policies such as land consolidation and floor area ratio incentives, they have implemented the integrated development of stations and their surrounding land, fostering compact urban growth [8]. Hong Kong, China has adopted the "rail + property" model for integrated transportation and land development, implementing high-density comprehensive development around each station to form a bead-like urban structure underpinned by rail transit [9]. With the advancement of urbanization in mainland China, diverse rail transit networks have been constructed and gradually refined. Scholars have initiated research on the significant role of railways in the social economy, particularly in urban development, encompassing areas such as rail transit passenger flow forecasting, network design, station planning, TOD development pathways, and development level evaluation [10–13].

Most existing research focuses on spatial dimensions. However, a critical consideration is that transit requires time to facilitate spatial transfers, and the efficiency of such temporal-spatial conversion directly influences the operation of the social economy. In discussions of rail transit and urban development, time constitutes an inseparable dimension. This paper will investigate the impact of rail transit on urban development from an integrated temporal-spatial perspective.

3. Framework for the interactive development between the rail transit economic field and cities

As cities expand in scale and evolve into multi-centered structures, commuting distances have lengthened, and travel time to work has increased accordingly. However, the hours in a day are finite, leading to a growing temporal-spatial conflict within cities. Development experiences from cities like Tokyo and Hong Kong, China demonstrate that prioritizing rail transit and integrating transportation with land development is an effective solution to this conflict. In other words, it involves constructing an economic development model centered on rail transit to create a “rail transit economic field.”

3.1. Analysis of temporal-spatial characteristics and accessibility of rail transit systems

From the perspective of temporal-spatial economics, accessibility essentially refers to the ease or difficulty with which people or goods move across time and space. There are differences in the magnitude, efficiency, and scope of time-space transformation achieved by highway, railway, waterway, and air transportation, thus leading to variations in the accessibility of different transportation modes. **Table 1** shows the indicators that measure accessibility from these different angles. Both personal accessibility and regional accessibility are directly affected by how accessible the transportation mode itself is.

Rail transit is a form of public transportation that provides public service-oriented products, featuring mature technology and operation on dedicated networks. Compared to road traffic, rail transit operates in enclosed spaces—like specific “temporal-spatial tunnels”—and is minimally affected by external environments, offering stability, reliability, and high safety. **Figure 1** presents an analysis of the temporal-spatial characteristics and accessibility of rail transit systems.

Table 1. Accessibility analysis from different perspectives

Investigation objects	Main indicators affecting accessibility	Explanation of indicators
User accessibility	Distance between the user and the transportation system	The closer the user is to the transportation system, the more convenient it is to enter the transportation space, and the higher the accessibility.
	Efficiency of usable transport modes	The higher the efficiency of the transport modes available to the user, the higher the accessibility.
	User's travel preference	The higher the efficiency of the user-preferred transport mode, the stronger the accessibility.
	Income status	The better the user's income status, the wider the range of travel options, which may improve accessibility.
Regional accessibility	Land use density	The higher the land use density in the region, the shorter the space-time conversion distance may be, and the higher the accessibility.
	Degree of spatial function integration	The more integrated the regional functions, the shorter the space-time distance between functional areas may be, and the higher the accessibility.
	Dominant transport mode	The faster, larger-capacity, and more reliable the regional dominant transport mode is, the higher the accessibility.
	Traffic network density	The denser the traffic network per unit area in the region, the higher the accessibility.

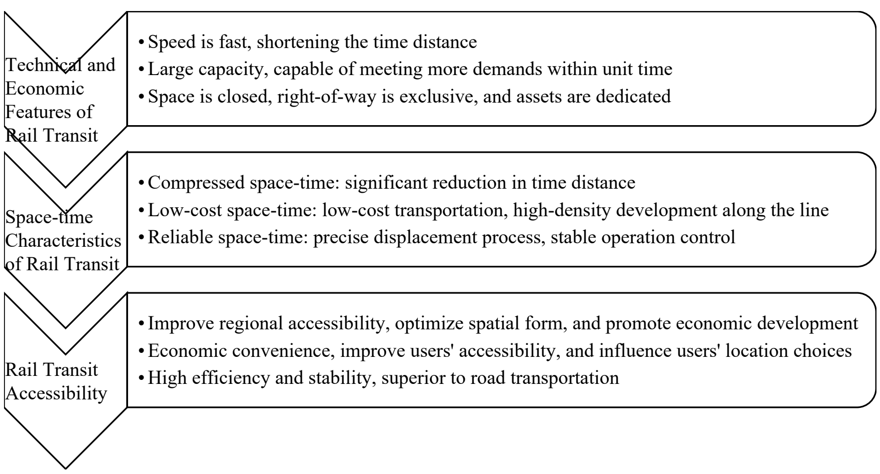

Figure 1. Features and accessibility analysis of rail transit systems

In urban clusters, metropolitan areas, and large cities, travel demand is high and distances are long. The development of a rail transit economic zone benefits both users and the areas along the route. For rail transit users, its advantages in technology and industry enhance mobility capabilities and reduce travel costs. As people perceive rail transit as more convenient, their travel preferences shift: they begin to choose residences or workplaces near rail transit stations and rely on rail as their primary mode of transportation. For regions with a railway network, due to the enhanced transportation capacity brought by railways, high-density development can be implemented, and the integration of functional spaces can be achieved. Its accessibility advantages also attract resources to gather around stations, strengthening the connection between rail transit and urban spaces.

Next, we will explore how rail transit economic fields influence urban temporal-spatial relationships and how rail transit and cities develop in synergy.

3.2. Pathways for interactive development between rail transit economic fields and urban Systems

Rail transit's significant advantage in accessibility greatly improves mobility for the surrounding areas and residents. This enhances the economic attractiveness of spaces around and along rail transit lines, drawing in populations, resources, and various economic activities to form a vibrant "rail transit economic field." Below is an analysis of how this economic field positively impacts spatial utilization, temporal utilization, and temporal-spatial connections in the region.

3.2.1. Impact of rail transit economic fields on spatial utilization

Rail transit is generally recognized as the urban transportation mode with the lowest per capita space consumption. Cities focus development on rail transit spaces, building compact, high-density areas along lines to integrate transportation functions with other urban functions, thereby significantly improving land-use efficiency. Since rail transit can transport far more passengers per hour than buses or private cars, it supports the integrated development of above-ground and underground spaces along lines. This enables cities to expand vertically, meeting the spatial needs of large, crowded metropolitan areas and urban clusters.

Thanks to the speed and reliability of rail transit, more destinations can be reached within the same time frame. This facilitates orderly urban growth along rail lines and supports the development of multi-centered city structures. As resources and functions gather along rail lines, the spaces in these areas become more diversified, comprehensive, and balanced. Many satellite cities can even undertake some non-core functions of the main city through the rail network, optimizing the distribution of urban functional fields to be more balanced and rational.

Improved accessibility and population inflow drive rapid growth in the commercial value of areas along rail lines. In turn, increased commercial development attracts more people and resources, forming a positive cycle. Additionally, compact development around rail transit occupies less surface space, reserving more area for urban green spaces and enhancing urban livability. The spatial utilization of rail transit economic fields is shown in **Figure 2**.

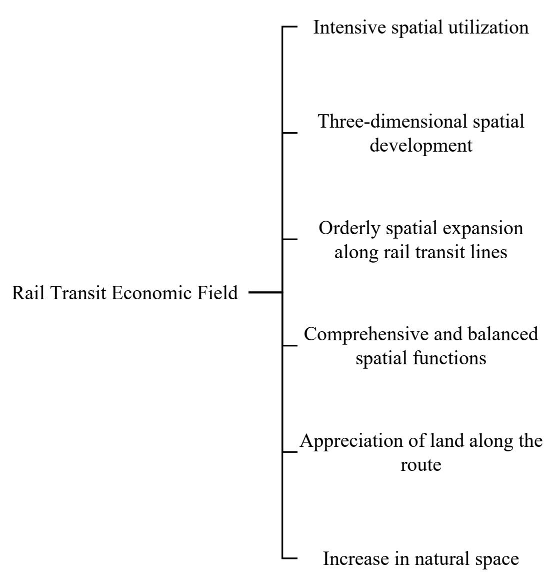

Figure 2. The spatial utilization of rail transit economic fields

3.2.2. Impact of rail transit economic fields on temporal utilization

In terms of optimizing temporal utilization, first, the high-density, mixed-use development along rail lines reduces the distance between different functional spaces, shortening travel distances and time. Second, rail transit's high speed saves travel time. In central areas of large cities, rail transit typically operates at 40–60 km/h—approximately twice the speed of regular road buses. Its speed is comparable to that of private cars, but while cars offer flexibility, increased road traffic leads to worse congestion, making car travel longer and more unpredictable. Thus, rail transit economic fields reduce commuting time and increase leisure time for residents [14].

Furthermore, rail transit hubs are evolving into multi-functional spaces with extensive surrounding development. This means that during travel, people can simultaneously engage in shopping, leisure activities, cultural visits, or entertainment—achieving "one-stop travel." Rail transit economic fields enhance the value of travel time.

3.2.3. Impact of rail transit economic fields on temporal-spatial connections

Benefiting from the compressed time-space, low-cost time-space, and reliable time-space enabled by the rail transit system, the circulation of factors within the rail transit economic field becomes more efficient, which can facilitate economic cooperation. More importantly, a stable chain of transportation trips is conducive to solidifying travel patterns, thereby fostering stable socio-economic relationships.

First, rail transit facilitates the establishment of new temporal-spatial connections between elements. High-density vertical development around rail hubs and along lines integrates diverse functional spaces, facilitating economic cooperation. Rail transit also expands the reach of elements, bridging time and space to connect economic factors even in distant regions.

Second, rail transit improves the efficiency of temporal-spatial conversion. Due to features such as dedicated enclosed tracks and high speed, temporal-spatial conversion within rail transit economic fields is generally more efficient than with road traffic.

Third, rail transit stabilizes temporal-spatial connections. Transportation converts physical distance into temporal distance, and limited time can constrain the growth, expansion, and movement of people and goods in large cities. Typically, temporal distance is calculated by dividing physical distance by speed (i.e., travel time). However, when accounting for time spent walking to stations, waiting for trains, or transferring, temporal distance becomes "connection time + travel time." Adding uncertainties like inclement weather, traffic jams, accidents, or breakdowns further complicates this temporal distance chain. Rail transit, with its reliable and consistent travel, simplifies this chain, reduces uncertainties, and fosters stable, long-term travel routines and economic connections.

3.2.4. Synergistic development of rail transit economic fields and cities

In summary, rail transit—with its technical, economic, and temporal-spatial advantages—alters urban spatial utilization, temporal utilization, and the temporal-spatial connections between elements. It enhances accessibility for regions and users, forming economic fields that transform urban land use in both dimension and density. The construction of rail networks and economic fields enables cities to grow orderly horizontally and develop compactly with high density vertically. Rail transit economic fields alleviate urban temporal-spatial conflicts and reduce unplanned, disorderly expansion. Conversely, as cities develop and their forms evolve, new transportation demands emerge, influencing the planning and construction of rail networks. This cyclical relationship between rail transit and urban development is illustrated in **Figure 3**.

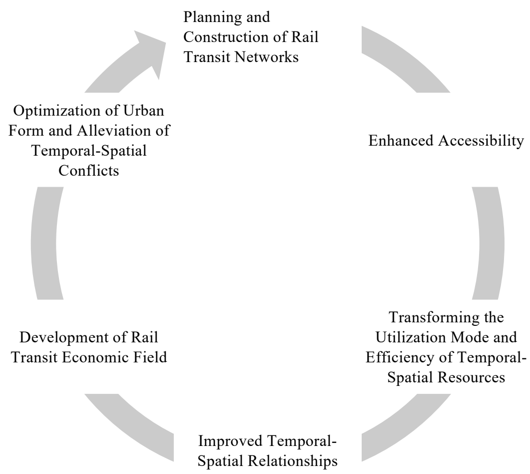

Figure 3. Logic of interactive development between rail transit and cities from a temporal-spatial perspective

3.3. Case study

The Tokyo Metropolitan Area, known as a "city on rails," has formed an efficient urban morphology through interactive development between rail transit and the city. Japan's private railway companies were the first to propose and practice the model of synchronizing rail construction with surrounding development. A key proponent was Yataro Kobayashi, founder of Hankyu Railway, giving rise to the "Yataro Kobayashi Model." This model is a typical example of reshaping urban temporal-spatial relationships through the formation and utilization of rail transit economic fields, with the following construction process: First, while building railways, develop residential areas, introduce department stores, and allocate various living facilities along the lines. Through compact development and spatial integration, improve accessibility and establish reliable temporal-spatial relationships to provide stable passenger flow for rail transit. Second, enhance the commercial value of areas along lines through improved accessibility and engage in diversified operations to generate profits. Third, dynamically and continuously advance the development of areas along rail transit lines to enhance the degree of dependence on rail transit for travel and consolidate temporal-spatial relationships. Ultimately, it forms a multi-centered, sustainable metropolitan area supported by a rail transit network.

The analysis of how rail transit economic fields influence time and space is equally applicable to the interior of urban agglomerations. Nantong City in the Yangtze River Delta is separated from Shanghai by a river, with a straight-line distance of less than 200 kilometers. Before the opening of the Shanghai-Suzhou-Nantong Railway, passenger trains from Nantong to Shanghai had to detour via Nanjing, taking at least 3.5 hours. In July 2020, the first phase of the Shanghai-Suzhou-Nantong Railway began operation, shortening the fastest travel time between Shanghai and Nantong to 1 hour and 6 minutes. Nantong thus entered Shanghai's 1-hour transportation circle, not only conveniently undertaking non-core functions transferred from Shanghai but also successively signing the "Strategic Cooperation Agreement on Strengthening Suzhou-Nantong Cross-River Integrated Development" with Suzhou and the "Strategic Cooperation Agreement on Strengthening Wuxi-Nantong Cross-River Integrated Development" with Wuxi. Rail transit has reshaped temporal-spatial relationships, thereby promoting economic cooperation within the urban agglomeration and optimizing the functional layout of the agglomeration.

4. Conclusion

There exists an interactive relationship between transportation and urban development, with the underlying logic being as follows: Economic development generates transportation demand, which in turn drives the construction of transportation networks. Conversely, transportation influences regional accessibility, guides the flow and allocation of resources, and shapes new urban morphologies. Owing to their distinct technical and economic attributes, different transportation modes exert varying impacts on regional accessibility. Rail transit, characterized by large capacity, high speed, stability, and reliability, is capable of meeting large-scale concentrated transportation needs, enhancing accessibility in areas along the lines, and forming a rail transit economic field centered on the rail network. The advantages of the rail transit economic field in urban development are summarized as follows:

(1) Through horizontal axial development and vertical three-dimensional high-density development, the rail transit economic field can satisfy the spatial demands of modern megacities.

(2) The rail transit economic field is conducive to establishing economic linkages, improving the efficiency of temporal-spatial conversion, and facilitating the consolidation of temporal-spatial relationships, thereby breaking through the temporal constraints in the process of megacity expansion.

(3) The rail transit economic field promotes the coexistence of urban spaces and natural environments through intensive land use.

The research framework of this paper also contributes to exploring the relationship between railways and economic development on a larger scale. It should be noted that this study only provides a qualitative explanation of the impact of the rail transit economic field on spatial, temporal, and temporal-spatial relationships. The efficiency of the rail transit economic field and its specific impacts on urban development require further verification through quantitative analysis.

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Disclosure statement

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