

## Review

# Research Progress of the Impacts of Comprehensive Transportation Network on Territorial Spatial Development and Protection

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**Abstract:** Coordination between the construction of transport infrastructure and the development and protection of territorial space is an important factor in promoting sustainable regional development, but there is still a lack of systematic research on the impact of transport on territorial space worldwide. Following the logic of “development trend revealing—theoretical and technological summary—mechanism analysis”, the research progress on the two aspects of development and protection of territorial space related to transport is systematically and comprehensively sorted from the perspective of multi-scale and multi-mode transport. The results show that: (1) The number of research papers on the effect of transport on territorial space is on the rise, and there is an obvious trend of cross-disciplinary research. (2) Transport infrastructure will promote the development of territorial space in terms of land use change, spatial-temporal compression, and economic development, and will affect the protection of territorial space in terms of ecological impacts, energy consumption and carbon emissions, and the crossing of protection zones. (3) In the existing research, the lack of multi-dimensional indicator system construction and analysis, insufficient research at the mechanism level, and insufficient combination of theoretical research and practical application are the main problems at present, and an important direction is urgently needed for future research.

**Keywords:** comprehensive transportation network; territorial spatial planning; development and protection; spatial effects; research progress



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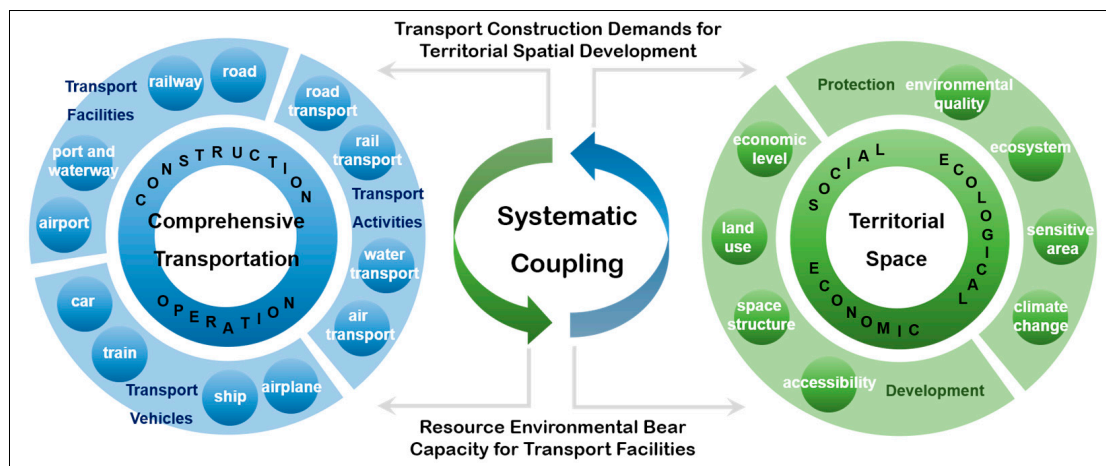
## 1. Introduction

With the rapid development of global urbanization, the rational development and protection of regional spatial resources have increasingly attracted the attention of urban planning researchers. The transportation network is the “skeleton” of regional economic and social development, and the construction of transportation infrastructure is closely related to the development and protection of territorial space [1]. An increasingly improved transportation network makes the connection between regions closer, accelerates the exchange and aggregation of logistics, energy flow, information flow, capital flow, and other flows, and effectively promotes regional development [2,3]. At the same time, the construction and operation of transportation facilities inevitably cause damage to the regional ecological environment [4,5]. Scientific and reasonable spatial and transportation planning will effectively promote the coordination of regional spatial development and protection, which is conducive to the sustainable development of the region.

Territorial space means the entire space comprising the territory, airspace, and territorial sea within the boundaries of the State, including the utilized and unutilized land

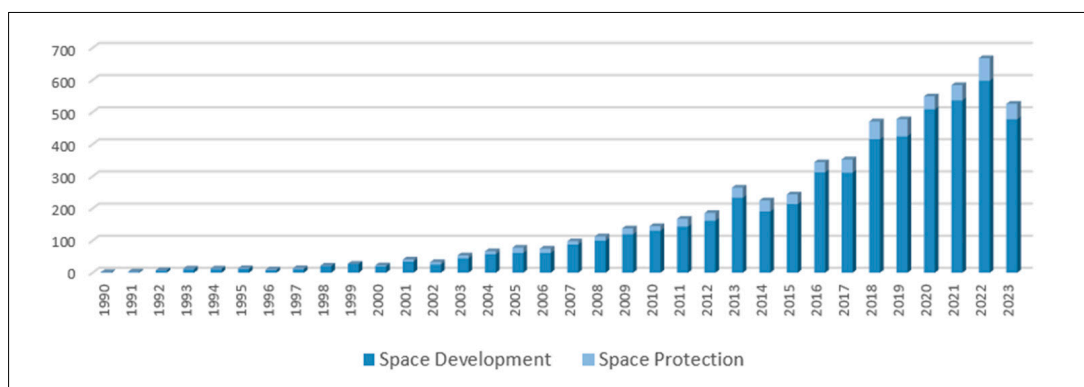
surface and the space above and below the surface of the water. Territorial space is the carrier of all social, economic, and ecological activities, and the rational development and protection of territorial space are crucial to the sustainable development of a region. The impact of transport construction on territorial space is very significant, and the coordination of the relationship between transport and territorial space is currently a major concern for all countries. Territorial spatial planning and transportation planning in countries all over the world often show close interaction; when territorial spatial planning focuses on development, transportation planning focuses on the supply side, and when territorial spatial planning focuses on control, transportation planning favors the demand side [6,7]. The functions and status of transportation planning vary at different times due to the differences in national policies for the development and protection of territorial space. At this stage, the Netherlands, Germany, and Japan have formed a more mature land-transportation planning system. The Netherlands has a streamlined territorial transportation planning system, and transportation planning is an important content of spatial planning and an important means of realizing spatial development strategies [8,9]; Germany's current transportation planning is categorized as a special plan in the spatial planning system, with strong spatial development attributes, especially in trans-regional infrastructure construction projects with high priority [10]. In 2001, Japan merged the Ministry of Construction, Transportation, Land and Hokkaido Development Office into the Ministry of Land, Infrastructure, Transportation and Tourism to plan and control national land space and transportation, and the national transportation network plan was prepared based on the national land formation plan, and the establishment and improvement of Japan's spatial planning system has played an important role in supporting the country's economic development and environmental protection [11].

At present, developing countries around the world are currently facing unprecedented urbanization development, and this rapid urbanization development is accompanied by a large amount of transport infrastructure construction. Emerging countries and regions are ushering in a golden period of integrated transport construction. China, India, Iran, Vietnam, Indonesia, and many other countries are vigorously developing urban rail transport and cross-regional road and railway transport. In China, for example, transport construction and territorial space development are important elements of current development, and it is particularly important to strengthen the synergy between the two. 2021, the Outline of the Fourteenth Five-Year Plan and Visionary Goals for National Economic and Social Development for the Year 2035, one of the most important plans for China's socio-economic development, proposes to put "two new and one important" (new urbanization, new infrastructure and major transportation, water conservancy, and energy projects) in a very prominent position; energy and other major transportation, water conservancy, and energy projects are given a very prominent position. The planning and construction of transportation infrastructure are crucial to the coordinated development of the region. Since the implementation of the strategy of a country with a strong transportation network, high-speed and accessible transportation networks have become the main driving force behind the high-speed development of the region [12]. At the same time, the developed transportation network inevitably has a certain impact on the regional ecological environment [13]. With the establishment of the territorial spatial planning system, the constraints of land resources and the ecological environment on the construction of transportation infrastructure have gradually come to the fore [14]. How to carry out a scientific assessment of the effect of transportation on territorial space, grasp the impact of cross-regional transportation infrastructure in different periods, different scopes, different types, and different fields, and promote the optimal layout of cross-regional transportation infrastructure and maximize the positive effect has become a problem that needs to be solved urgently by academics and decision-making departments at present [15] (Figure 1).



**Figure 1.** Coupling of comprehensive transportation and territorial space.

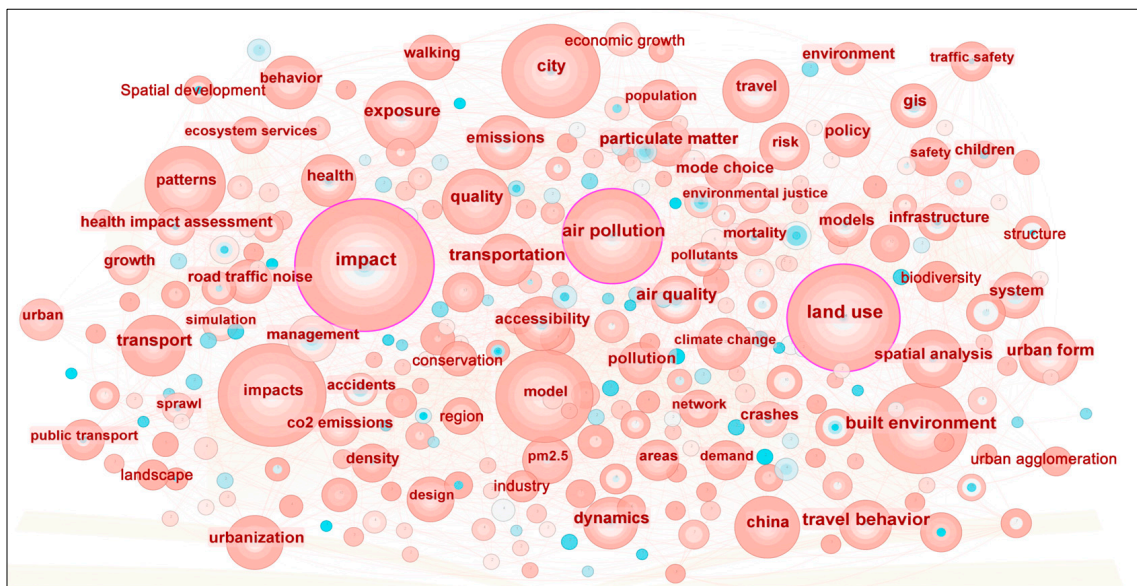
The bibliometric method can reveal the associated characteristics and changing law of the research object through quantitative statistical analysis from the perspective of interdisciplinary perspective and visualization [16]. Based on the core collection database of Web of Science, this paper conducts a literature search on the topics “transportation”, “development and protection”, “impact” and “spatial planning”. After eliminating irrelevant items such as reports, academic developments and information columns, a total of 3206 relevant literatures were obtained at 25 December 2023. As a whole, the research on the effects of transportation on spatial development and protection shows a rising trend year by year, and the research results on spatial development are more than those on spatial protection. From the perspective of the origin of the research, the related research mainly originated from the developed countries in Europe and America, but the number of related research articles was relatively small in the initial stage, and the number of articles in the related field began to show a rapid growth trend around 2000 and peaked in the last three years, indicating that after the 21st century, the research on the development and protection of transportation and space has gradually been paid attention to, and has become a research hotspot in recent years (Figure 2).



**Figure 2.** Statistics on the number of years of literature related to “Transportation impacts on spatial development and protection of the national territory”.

Using the bibliometric visual analysis software Citespace to analyze the research directions and hotspots, the literature was imported with the interval set to 1 year and the nodes set to keywords, and the main areas of research and research hotspot mapping were obtained after finishing. From the mapping, it can be seen that the main hot words of the research related to the development and protection of space by transportation are air pollution, land use, transportation network, spatial structure, economic growth, impact,

city and region, accessibility, and so on. Judging from the degree of association of each keyword, the relevant research fields of the established literature are relatively broad, involving various social, economic, and ecological factors, and the themes of land use, economic growth, and air pollution are the hot spots of long-term concern and research in the academic community. In addition, with the development of urban agglomerations and the construction of high-speed railroads, the impact of high-speed transportation on land space at the regional level has also become a hot topic (Figure 3).



**Figure 3.** Keyword co-occurrence map of literatures.

Focusing on the impacts of transportation networks on territorial space and based on the background of territorial space development and protection, the review is carried out along the lines of theoretical foundation, effect assessment, research evaluation, and outlook, aiming at sorting out the history of the research on the territorial spatial effect of transport and elucidating the specific impacts of transport on the development and protection of territorial space and the mechanisms by which they are generated. Firstly, from the perspective of the development of territorial space, research on the impact of transportation on land use protection, spatial and temporal compression effects, and economic development level of regions and cities is sorted out. Secondly, from the perspective of protection of territorial space, research on ecological evaluation of ecological impacts of construction and operation of transportation infrastructures, carbon emissions from transportation, and crossing of protected areas is sorted out. Thirdly, based on the above research on the impacts of transportation on territorial space, we summarize the mechanism of the impact of transportation on territorial space and put forward a review of the existing research and future development prospects. The main contribution of this paper is to systematically and comprehensively sort out the research related to the territorial spatial effects of transport, including diversified research dimensions (development and protection of territorial space), multi-scale research areas (urban agglomerations and intra-cities), and different types of transport infrastructures (highways, railways, airways, and waterways), with rich and high-quality literature. It provides a broader perspective on the established research in the field and will also provide some references for subsequent theoretical studies and practical construction projects. The aim is to explore a way to realize high-quality regional development driven by transportation under the constraints of resource management and control, and to change from focusing on scale growth to coordinated regional and green development.



## 2. Impacts of Regional Transportation Network on Territorial Spatial Development

### 2.1. Impacts of the Transportation Network on the Development and Use of Land along the Routes

The research on the impacts of transportation networks on land use originated in the United States. In 1971, the U.S. Department of Transportation put forward the “*transportation development and land development*” research topic for the interaction between urban land use and transportation systems to carry out a comprehensive study [17]. In 1988, Schütz et al. analyzed the land around the railway station and put forward the “*three development zones*” circle structure model [18]. In 1989, de la Barra put forward the model theory of transportation and comprehensive land use in “*comprehensive land use and transportation construction*” [19]. After 1990, with the introduction and wide dissemination of the TOD theory, research on the impact of transportation facilities on urban land use focused on the change of transportation on urban land use types [20], development intensity, and the impact of transportation on urban land use efficiency and land price [21,22], and the transportation and land use integration model is the main research tool in this field [23,24]. As far as the existing research is concerned, the theory and practice about the impacts of intra-city transportation on land use have tended to mature, while the research on a larger scale is still in its infancy. In recent years, with the development of regional transportation integration, the effects of intercity transportation on land use in urban agglomerations and metropolitan areas have become one of the main directions of future research [25,26]. At present, existing studies have mainly analyzed the changes in land use over different time periods through the establishment of buffer zones of high-speed railway or motorway lines [27,28].

### 2.2. Spatial and Temporal Compression Effect of Regional Transportation Network

The spatial and temporal compression effect of the transportation network is mainly reflected in two aspects. First, the construction of transportation facilities will shorten the spatial and temporal distance between cities, reduce the time needed for passenger and freight transportation, produce spatial and temporal convergence, and promote economic and social ties between cities [29]. Secondly, the improvement of the transportation network will change the degree of transportation advantage of each city in the region and then affect the overall spatial structure of the region [30]. Accessibility is an important indicator for measuring the structure and distribution of the transportation network, and the most basic reflection of the shortening of spatial and temporal distance between cities is the improvement of accessibility [31]. Accessibility, first proposed by Hansen, refers to the size of the interaction opportunities of the nodes in the transportation network, and also refers to the convenience of using a specific transportation system to reach a designated place from a certain location [32]. Regarding accessibility metrics, current research mainly considers two aspects: travel cost and location attractiveness [33,34]. The indicators often used for travel cost include the shortest time between origin and destination, distance, and cost [35–37]. And at the same time, some studies have also taken safety and comfort as evaluation indexes [38,39]. As for location attractiveness, it is often measured using indicators such as the level of regional economic development and the number of populations [40]. Studies on the impacts of transportation construction on urban space cover regional and urban agglomeration, city, and station area scales [41], and it is generally believed that changes in spatial structure at macro-regional scales mainly originate from the construction of trans-regional transport corridors such as roads and railways [42,43]. JIN Fengjun et al. integrated the indicators of regional transportation network density, the degree of influence of transportation arterials, and the degree of locational advantage and put forward the concept of the degree of transportation advantage [44]. The increase in the degree of transportation advantage is considered to be the result of the spatial and temporal compression effects of transportation, which change the regional spatial structure. The study of city and station area scale can be traced back to the emergence of industrial location theory and land rent theory. Differences in the accessibility of different areas will significantly affect the

spatial form, scope, and structure of the city, with a special functional area often forming around metro or bus hub areas with high accessibility [45,46].

### 2.3. Impacts of Transportation Network on the Regional Economy

The impacts of the transportation network on the regional economy can be reflected in two aspects. Firstly, the investment in transport construction will stimulate economic growth, expand production demand, and promote employment in the initial period [47,48], and the endogenous growth model and input-output model are the main measurement tools for this type of economic effect [49,50]. Secondly, the spatio-temporal compression effect of transportation will enhance the logistics and transport efficiency of the region, which in turn will strengthen the economic ties of the cities along the route [51], and this process is reflected in the impact of transportation infrastructure on economic agglomeration and growth, specialization, production efficiency, investment, and industrial structure. It is generally agreed that the main mechanism of the economic impacts of the transportation network on urban and regional space is: “changes in transportation accessibility—spatial and temporal compression effects—urban and regional economic development” [52]. The assessment of regional economic effects in existing studies can be divided into two categories: one based on multiple linear regression, accessibility model, system dynamics theory, etc., to construct the correlation between infrastructure and regional economy and analyze its generating mechanism [53,54]. The second is based on scenario analysis to reveal the results of economic development under the scenario of infrastructure presence or absence, and the way of measuring the economic linkage between the cities concerned is mainly realized through the gravitational model, e.g., [55], WANG Jiao’e et al. based on the GIS network analysis tool to study the economic intensity of the linkage between the cities in China under the three scenarios of no high-speed rail, the status quo of high-speed rail, and the planning of high-speed rail [56].

### 2.4. Comment on the Study of Transport Territorial Spatial Development

The research on the impact of transport network construction on territorial spatial development has evolved from the evaluation of a single indicator to the generation of theories, and then to the analysis of the comprehensive socio-economic effects of regional transport networks. Before 1980, the focus of the research was on the analysis of indicators such as economy and accessibility, and the research on the development of land along the roads driven by transport was in the embryonic stage. From 1980 to 2000, the theoretical methods of the impact of transport on spatial development began to appear, such as the spatial and temporal compression effect, integration of transport and land development, TOD theory, and gravity model, which provided a solid foundation for the research. After the 21st century, the promotion of urban rail transit on land development and land price appreciation, high-speed transportation to promote the reconstruction of regional spatial structure, strengthening economic links and industrial division of labor, and other content have become the focus of academic attention (Table 1).

**Table 1.** Sorting out relevant studies on the impact of integrated transport on spatial development of national territory.

Periods	Representative Scholars	Main View Points
Before 1980	Osullivan P, Wu C	Road construction will promote urban social and economic development [57,58]
	Akpan I, Kreibich V	Urban transportation system evaluation includes accessibility to regional opportunities, economic efficiency, community disruption, pollution of environment, and other indicators [59,60]
	Roeseler W, Taylor M A	Urban construction and land development are mutually promoting [61,62]

Table 1. Cont.

Periods	Representative Scholars	Main View Points
1980–2000	Miller H J, Levinson D M, Bruinsma F	The improvement of accessibility will produce a space-time compression effect, which will increase the demand for urban travel [63–65]
	Cervero R, Huber H J	The construction of transportation facilities will enhance the development intensity of land and transform non-construction land into construction land [66,67]
	Konings R, Airey A	Road construction will promote regional economic development and industrial upgrading [68,69]
2000–2010	Wang J, Luo P, Henderson V	The construction of regional transportation network will promote the economic ties between cities, and then promote the development of urban agglomerations [56,70,71]
	Mikelbank B A, Lim Duck-Ho	The construction of transportation facilities (especially urban rail transit) will help increase the overall land value of the city [72,73]
	Kveiborg O, Valackiene A, Li W	The transportation industry has a strong correlation with the development of national economy. Road and railway have made great contributions to the development of the economy [74–76]
2010–present	Zhao P, Li R	Mechanism research: Reasonable land use structure and layout can optimize travel demand, and the spatial and temporal distribution of transportation demand and transportation facility layout affect land price, thus further affecting urban land use [23,77]
	Jiao J, Jin F	The high-speed rail network will bring substantial improvement in the overall regional accessibility, but also increase the inequality of the transportation advantage of node cities [78,79]
	Lu H, Kruszyna M, Baum-Snow N	The development mode of regional spatial structure of urban agglomerations and the intercity transportation layout influences each other [80–82]

### 3. Impacts of Regional Transportation Network on Territorial Spatial Protection

#### 3.1. Ecological Impacts Assessment of Transportation Facilities

While promoting rapid economic and social development, transportation construction also adversely affects ecosystems and causes various environmental problems. Therefore, there is a need to provide sufficient scientific references to resolve the conflicts between transportation construction and ecological degradation [83]. The evaluation of the ecological and environmental effects of infrastructure originated in North America, and the term “*environmental impact assessment*” was first coined in 1964 at a conference on environmental quality assessment held in Canada [84]. In 1969, the *U.S. National Environmental Policy Act* stipulated that all federal funding projects must carry out an environmental impact assessment, which covers land use, biodiversity, water quality, marine environment, etc. [85], and the environmental evaluation in this period focused only on the natural environment. Into the 1990s, the issue of global ecological climate change received wide attention, the coverage of environmental impact assessment began to expand, the synergy and sustainable development of society–economy–ecology became the focus of research in that period, strategic environmental impact assessment was widely implemented in international organizations and developed countries in Europe and the United States [86], and environmental impact assessment began to be institutionalized. At the same time, research on ecological effects in the fields of ecosystems, landscape patterns, climate, and air quality gradually increased [87,88]. The object of ecological environmental impact assessment is also no longer limited to ecologically sensitive areas, and research on the impact of transport infrastructure construction on inner-city ecology, climate, and species diversity has begun to increase. A system of ecological and environmental impact assessment methods based on before-and-after comparison, scenario analysis, cumulative environmental impact assessment, risk assessment, and environmental carrying capacity evaluation has gradually been formed [89]. In 2003, the book *Road Ecology: Science and Answers* by R.

T. T. Forman was published, marking the beginning of the emerging discipline of road ecology [90]. The impacts of transportation corridors on biological populations and their habitats, geology, hydrology, atmospheric environment, the construction of ecological roads, the development of ecological transportation policies, and so on became the main content of this discipline [91]. In recent years, research on the development of transportation construction and ecosystem impact assessment around the world has been hot, mainly including the degree of impact of transportation facilities on ecosystems along the routes, mechanisms, future impact prediction, and optimization studies [92,93]. The analysis of the degree of impact and mechanism is mainly based on field observation, remote sensing images, and profile line analysis to measure the indicators of ecological land scale, biodiversity, and degree of landscape fragmentation in different periods [94] and to compare the ecosystem conditions before and after the construction of transportation facilities [95]. Regarding the cumulative impacts of transportation facilities on ecosystems and future predictions, mathematical and statistical models are often used to reveal the correlation between the construction and operation of transportation facilities and ecosystem indicators. At the same time, some researchers also use the DPSIR (Driver-Pressure-State-Impact-Response) model, CA (Cellular Automata), and STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) model to conduct computer simulation and calculation [96,97].

### 3.2. Relationship between Transportation Network and Regional Carbon Emissions

Carbon emissions are a hot topic in the field of ecological research. As far as China is concerned, the transportation industry, as a basic and supportive industry of the national economy, accounts for about 25% of the total carbon emissions of the whole society and is an important source of the total carbon emissions of the whole country, which cannot be ignored [98]. From the point of view of existing studies, the research on the impacts of transportation on carbon emissions is roughly divided into three parts: carbon emissions measurement [99,100], factors affecting carbon emissions [101,102], and research on emission reduction strategies [103,104]. For the measurement of carbon emissions from transportation, there is no uniform standard, and the international methods for estimating carbon emissions are mainly based on direct measurement, material conservation, and emission factors [105]. The specific measurement methods are top-down (calculating carbon emissions based on known energy consumption data and energy conversion factors) and bottom-up (quantifying carbon emissions through data on vehicle type, ownership, mileage, and unit mileage fuel consumption). The bottom-up approach is limited to small-scale use due to the high cost of acquiring data, while the top-down approach is more suitable for the measurement of regional transportation carbon emissions [106]. Regarding the analysis of carbon-emission influencing factors, the LMDI (Logarithmic Mean Divisia Index) factor decomposition model and regression model are the main tools for this type of research [107]. Emission reduction measures are one of the focuses of transportation carbon emission research, and most of the existing studies start with scenario simulation to analyze the effects of policy formulation, technology enhancement, etc. on regional carbon emission reduction [108]. And it is currently believed that the application of clean energy and energy-saving technologies for transportation, the improvement of transportation accessibility, and public-rail intermodal transportation are more effective carbon reduction options [109].

### 3.3. Impacts of the Transportation Network on the Conservation Area

Due to the unique biodiversity of protected areas and the fragility of the ecological environment, it is necessary to explore the impacts of transportation networks crossing protected areas on the ecological environment along the routes [110]. The construction and operation of transportation infrastructure can transform the original land use in protected areas, prompting changes in landscape patterns and leading to ecosystem degradation through fragmentation, disturbance, destruction, and pollution [111,112]. Research on



the impact of transportation on protected areas originated from Oxley's analysis of small and medium-sized mammal species and abundance in areas along some highways in Ontario and Quebec, Canada, in the 1970s, which focused on the hazardous effects of highways on biodiversity [113]. After the 1990s, with the start of road ecology research, studies about vegetation cover, species diversity, and the number and size of ecological patches along transportation routes in protected areas began [114,115]. In China, the relevant research began in 2000, and so far, there are mature empirical research results covering the analysis of the impacts of highways on land, water, flora and fauna, acoustic, atmospheric, and other factors in nature reserves and the construction of an evaluation index system [116]. Territorial space and its ecosystems are a source of environmental goods and services essential to the social and economic activities of countries. While transport infrastructure enhances the accessibility of territorial space and promotes socio-economic development, it also converts a large amount of ecological and agricultural land into land for urban construction, an almost irreversible construction activity that will eliminate the value of ecosystems and their environmental services, with serious impacts, especially on ecologically sensitive protected areas. Under the background of "three zones and three lines" of territorial spatial planning (the "three zones" refer to three types of territorial space, namely, urban space, agricultural space, and ecological space). And the "three lines" correspond to the three control lines, namely, the urban development boundary, the permanent basic farmland, and the red line of ecological protection, which are delineated in the urban, agricultural, and ecological spaces, respectively. The conflicts and contradictions between transportation lines and ecological and agricultural land have gradually come to the forefront, and transportation facilities are facing increasingly serious development constraints [117]. In this regard, relevant scholars believe that the mechanism of permanent basic farmland occupation and deployment of transportation linear projects should be established, and the control rules for harmlessly crossing the red line of ecological protection should be adopted in time for the post-evaluation of environmental impacts and ecological restoration work [118]. In addition, in order to promote the harmonious development of transportation construction and protected area ecology, with the introduction of concepts such as green highways and eco-highways, measures such as the construction of animal passages and ecological restoration along transport routes have effectively mitigated the impact of roads on ecosystem disturbance and blockage. MA et al. put forward the concept of an ecologically integrated transportation network of urban agglomerations, which coordinates the relationship between economy and ecology during the construction of transportation networks, not only realizes the unique function of transportation but also overcomes the negative characteristics of transportation and promotes the development of urban agglomerations' integrated transportation systems in a low-carbon and green way [119].

#### *3.4. Comment on the Study of Transport Territorial Spatial Protection*

Research on the impact of transport networks on the protection of territorial space has evolved from the analysis of a single natural component to the construction of environmental impact assessment theories, and then to the coordinated development of transport and the ecological environment. The research originated from an analysis of the impacts of roads on the number of species and air pollution. After 1980, the transportation impacts of each component of the ecosystem were included in the scope of research, and the theoretical system of environmental impact assessment was initially formed. After 2000, with the accelerated urbanization process in developing countries, the contradiction between transportation and ecology was highlighted, and how to build environmentally friendly transport facilities became the focus of current research (Table 2).

**Table 2.** Sorting out relevant studies on the impact of integrated transport on spatial protection of national territory.

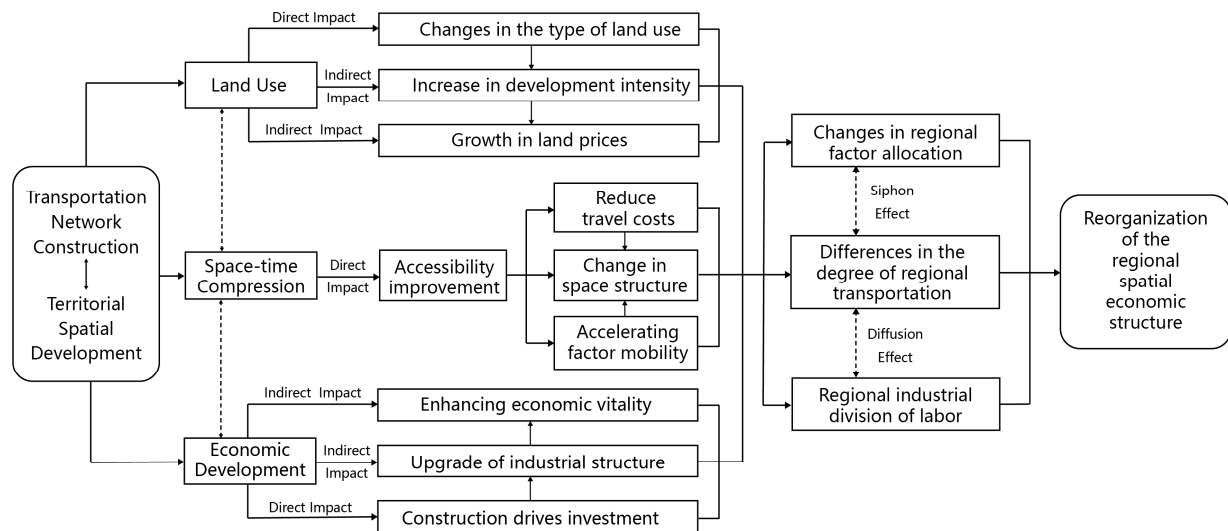
Periods	Representative Scholars	Main Points
Before 1980	Oxley, Nijima K, Rost G R	Road construction will affect the habitat environment of wildlife, causing animals to move away from the road area [113,120,121]
	Mahoney J R, S. Trivikrama Rao	Transportation will promote the diffusion of air pollutants around roads [122,123]
1980–2000	Bielli M, Extence C A, Frost S	The burden on the environment caused by the transport sector seriously affects ecological sustainability, producing noise, air, farmland, and water pollution [124–126]
	Hall P, Dunne B, Morgan R K	Environmental impact assessment analysis of countries around the world [127–129]
	Wulff A, Michaelis L	Improvements in vehicle energy efficiency and transport policies can greatly help reduce greenhouse gas emissions [130,131]
2000–2010	Forman R T T, Schweitzer L, Coffin A W	Road ecology: Transport infrastructure affects ecosystem structure, ecosystem functional dynamics, and directly affects ecosystem components, including their species composition [90,132,133]
	Hawbaker T J, Liu S, Eliou N	The influence of roads on landscape pattern increases with the increase of the grade, and the degree of landscape fragmentation intensifies with the expansion of the network [134–136]
2010–present	Sangho C, Macias A	The conflict between transportation and ecological environment in the metropolitan area is very significant. A large number of high-flow roads lead to fragmentation of natural areas [137,138]
	Lin Y, Li H, Irimie L S	The improvement of transportation accessibility can improve the value of regional ecological environment services and reduce environmental pollution by reducing transportation congestion and shortening transportation mileage [139–141]
	Andersson E, Juffe-Bignoli D	Ecological harmless measures in the planning and construction of interregional development corridors will effectively reduce the impact of roads on the ecological environment along the routes [142,143]

#### 4. Mechanisms of Territorial Spatial Role of Transportation Network

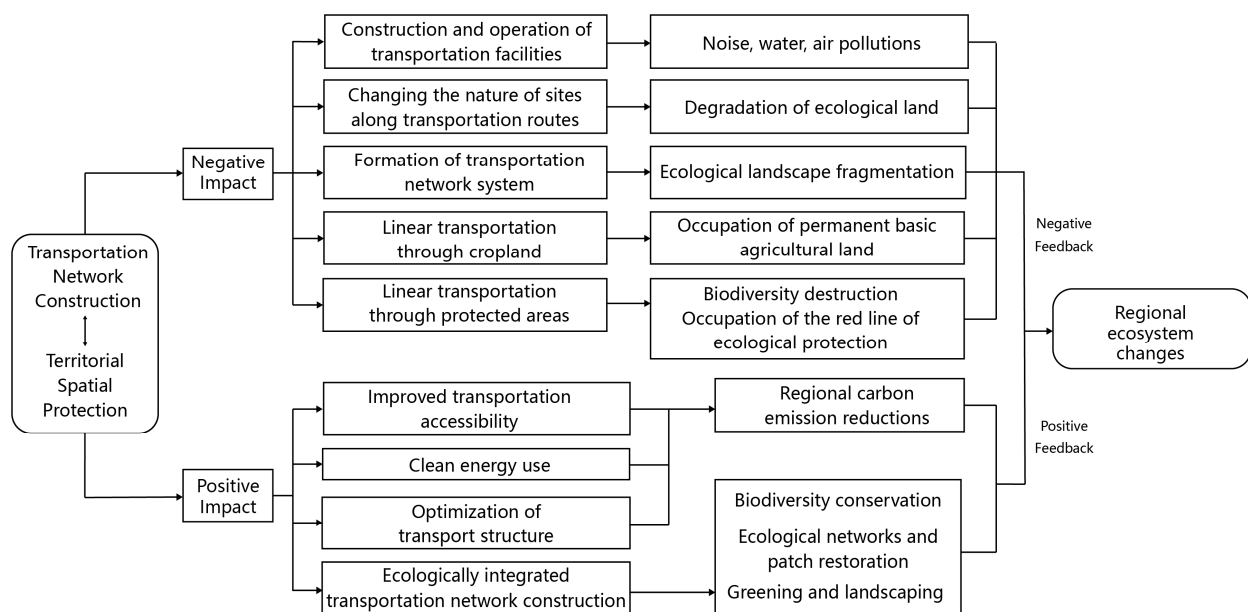
The influences of transportation on the development of territorial space (Figure 4): Firstly, the construction of transportation infrastructure will promote the change of land along the route from non-construction land to construction land, enhance the development intensity of land, and then promote the increase in land price; secondly, the improvement of the transportation network will enhance the accessibility of the region, and the cost of passenger and freight transportation will be reduced, and the spatial structure of the region and the city will be changed accordingly [144,145]; lastly, the construction of the transportation infrastructure will contribute to the enhancement of economic vitality by directly pulling investment and indirectly promoting the upgrading of the regional industrial structure. Based on the above three influences, transportation will cause differences in the degree of regional transportation advantages, which will in turn promote changes in the allocation of regional factors and the further division of labor and cooperation of industries and ultimately lead to the reorganization of regional spatial and economic structure.

With regard to the impacts of transportation on the protection of territorial space (Figure 5): From the point of view of the negative effects of transportation infrastructure, the construction and operation of transportation will result in noise, water, and atmospheric pollution; the degradation of ecological land [146,147]; the fragmentation of landscapes [148,149]; the occupation and fragmentation of protected areas [150,151]; and the destruction of species diversity [152,153]. From the perspective of positive effects of transportation infrastructure, the improvement of transportation accessibility, the use of clean energy, and the optimization of transportation structure will be conducive to the reduction of regional carbon emissions [154,155]; the construction of an ecologically inte-

grated transportation network will promote the ecological restoration of areas along the routes [156,157]. Based on the superposition of positive and negative effects, transportation facilities will ultimately affect changes in the regional ecological environment systems.



**Figure 4.** Mechanism of transportation influence on territorial space development.



**Figure 5.** Mechanism of transportation influence on territorial space protection.

## 5. Conclusions and Prospects

Based on some innovative points: wider geographical research, different types of transport infrastructure, and more up-to-date evidence, this paper, by combing and summarizing the research results on the territorial spatial effects of transport, objectively analyzes the research history, evolutionary law, and mechanism of the role of transport infrastructure construction on territorial spatial development and protection, and reveals the hotspots of the research on transport and spatial planning at both the theoretical and practical levels, so as to provide some theoretical basis and references for more in-depth future. It provides a certain theoretical basis and reference for more in-depth research in the future.

There is a wealth of research on the impact of transportation networks on spatial development and protection of territory in the existing literature, but in general, there are

still some shortcomings in the relevant research. In terms of the impact of transportation on the spatial development of the territory, although the existing studies are multi-dimensional in scale, most of the research areas are located in economically developed regions, such as London, Paris, and the three major urban agglomerations in China, and there are fewer studies in economically underdeveloped regions. Secondly, the research results are mostly empirical analysis, and there is insufficient thinking on the theoretical system and analytical structure. In terms of the impact of transportation on the spatial protection of the territory, the existing research mainly focuses on a single mode of transportation. As an important force to promote regional development, the comprehensive transportation system integrates various modes of transportation such as railroads, highways, aviation, water transportation, and so on, and the scientific evaluation of the ecological effect of the integration of various modes of transportation will be the content of the future research that needs to be focused on. In addition, as the individual evaluation methods of the spatial effects of transportation on the territory have matured, how to build a comprehensive evaluation standard system and enhance the scientific, systematic, and accurate assessment results with a unified research paradigm and methodology are common problems faced by all parties.

In view of the shortcomings of the existing studies, we make the following recommendations. Firstly, improve the assessment methods and technical research on the effect of transportation networks on territorial space. In the context of high-quality development, China is in a critical period of optimizing the spatial pattern of the national territory, and how to correctly assess the differentiated effects of transportation infrastructure on the territorial space plays an important role in the optimization of the spatial pattern of the national territory at all levels and regional development. Meanwhile, with the diversification of transportation modes and the construction of a comprehensive transportation system, the idea of integrated analysis and evaluation with the comprehensive transportation network as the research object needs to be further clarified.

Secondly, the theoretical research on the mechanism and mechanism of the influence of transportation on national territory space should be emphasized. Although there are a large number of studies on the impact of transportation on land use, accessibility, economy, ecology, and other aspects of existing research, the main focus is on the description and analysis of the phenomenon. The discussion on the mechanism of the impact of the transportation network on regional social, economic, and ecological aspects is not yet in-depth and still needs to be further explored. In the future, we should strengthen the analysis of the influencing factors, characteristics, development process, and mechanism of the spatial effects of the transportation network on the territory, so as to put forward more targeted decision-making suggestions.

Thirdly, the connection between basic research and practical application should be strengthened. At present, basic research on the optimization of land space and transportation has matured, but there is still a lack of research on the scientific planning of transportation infrastructure, the rational layout of routes, and the calculation of transportation construction capacity under the carrying capacity of certain resources and environment. Therefore, it is necessary to further strengthen quantitative research on the relevant content, so as to realize the coordination with the resources and environment and the synergy of regional development.

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