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*DEVELOPMENT OF TRANSPORT INFRASTRUCTURE AND ITS IMPACT ON TERRITORIAL PRODUCTION†

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Abstract. The purpose of this article is the conceptualization and empirical interpretation of the notions of a developed transport infrastructure and developed production, as well as the identification of tools for their measurement in a territory. The main research questions to which the authors intend to find answers in this article are the following: (1) what does it mean (conceptually and empirically) 'developed transport infrastructure' and 'developed production' in a given territory? (2) how to measure the state of development (i.e., the static level of development) of transport infrastructure and production in a given territory? The article uses the following research methods: a systemic analysis of theoretical findings and empirical evidence from previous studies, a method of means for identifying developed / underdeveloped transport infrastructure/production, and a mapping method to assess the strengths and weaknesses of the country's transport infrastructure. The results of this study show that, firstly, there are two main approaches to the conceptual understanding of transport infrastructure and production – traditional (narrower) and innovative (wider); secondly, developed transport infrastructure and developed products in the EU country are interpreted empirically with scores above the EU average, thirdly, almost all EU countries demonstrate a developed or undeveloped transport infrastructure and production, regardless of their measurement tools, i.e. different measurement tools show nearly the same result. The results of this study will help the authors in the future, based on quantitative empirical data and case studies, to answer the 'umbrella' research question about what is a priority for the economic development of the territory: a developed transport infrastructure or a developed production, i.e. what is the focus for investments in the conditions of objectively limited resources?

Keywords: transport infrastructure; territorial production; developed transport infrastructure; developed production.

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1. Introduction

The development of transport infrastructure, as well as the development of production in a territory, has been the subject of many economic studies. In particular, the development of transport infrastructure in the region is studied by economists specializing in transport economics (Melo et al., 2013; Boruch, 2014; Skorobogatova & Kuzmina-Merlino, 2017; Gherghina et al., 2018; Ferrari et al., 2019a, 2019b; Zhang & Qi, 2021). They distinguish several types of transport infrastructure in the territory – road, inland waterways, maritime, railway and air transport infrastructure, each of which may have a different significance for the economic development of a particular territory. In turn, the study of the development of production in the region is one of the main tasks of economists specializing in industrial economics (Garofoli, 1993; Kamols et al., 2014; Yong, 2021) and an additional 'background' task for economists working in the field of the post-industrial economics (Dwight Hines, 2011; Aamir et al., 2019; Orynbassarova et al., 2019; Petrenko et al., 2019; Bole et al., 2022). And here, economists also distinguish different types of production – agricultural, industrial, and post-industrial, for each of which the transport infrastructure has a different meaning.

As for the relationship between the development of transport infrastructure and the development of production in a given territory, there are many studies devoted to the impact of transport infrastructure on long-term development / growth (Gherghina et al., 2018; Wang et al., 2018; Cigu et al., 2018; Prus & Sikora, 2021) or territory competitiveness (Purwanto et al., 2017). Most of the above studies show that transport infrastructure has an enormous impact on the sustainable development of the territory, especially in the urban part (Aamir et al., 2019), but not just on the development of production. Concerning investments in transport infrastructure, the results of empirical studies exhibit a positive impact on territory's economic growth for every type of transport, except inland waterways (Gherghina et al., 2018). The book “Economic Role of Transport Infrastructure: Theory and Models” (2019) analyzes transport infrastructure’s impact on economic growth using theoretical frameworks, including exogenous growth models, endogenous growth models, and new economic geography models (Ferrari et al., 2019a). However, the general scientific interest of the authors of this study is limited to the relationship between the state of development of transport infrastructure and the state of development of production (but not regional development or economic growth) in a territory.

The purpose of this article is the conceptualization and empirical interpretation of the notions of a developed transport infrastructure and developed production, as well as the identification of tools for their measurement in a territory. The main research questions to which the authors intend to find answers in this article are the following:
(1) what does it mean (conceptually and empirically) “developed transport infrastructure” and “developed production” in a given territory?
(2) how to measure the state of development (i.e., the static level of development – Selivanova-Fyodorova et al., 2019) of transport infrastructure and production in a given territory?

Based on the results of the above studies, the authors put forward a hypothesis that the priority for the economic development of the territory in the modern world is precisely the developed transport infrastructure, which, in turn, stimulates the growth of production, and not vice versa. However, the proof of the formulated hypothesis is more evident and unambiguous than it may seem at first glance. For example, the results of some global studies showed that the effect of transport infrastructure on the development of production in the territory is higher in the US than in European countries, it is higher for roads compared to other modes of transport, and it is higher for the primary sector, manufacturing, and construction (Melo et al., 2013). Research results show that the transport infrastructure & production growth nexus is mysterious, particularly in Africa, because many rural farmers need their transport means (Iimi et al., 2018).

Even those studies that prove the positive impact of developed transport infrastructure on the development of production but at the same time consider the environmental component of the industrial output in the territory,

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however, indicate that transport infrastructure significantly contributes to industrial pollution emissions (Wang et al., 2022; Mesjasz-Lech & Wlodarczyk, 2022). This aspect, according to the authors, to a certain extent devalues the development of territorial production based on the developed transport infrastructure, which is especially important given the fact that in the knowledge economy, the transfer of knowledge and high technology, as well as their successful adoption, assimilation, transformation and exploitation, depend on the absorptive capacity of enterprises (Šimelytė & Tvaronaviciene, 2022), and not on developed transport infrastructure.

For the authors to have the opportunity in their further research to scientifically clarify, prove or refute the hypothesis put forward about the priority of a developed transport infrastructure for the economic development of the territory in the modern world, it is necessary, first of all, to conceptualize and empirically interpret the notions of both a developed transport infrastructure and a developed production, as well as to develop tools for their measurement in the territory. This will be done in the framework of this article, which is a theoretical and methodological study, as a basis for the further empirical study of the direction and nature of the relationship between the developed transport infrastructure and developed production in the territory. The article uses the following research methods: a systemic analysis of theoretical findings and empirical evidence from previous studies, as well as a method of means for identifying developed/underdeveloped transport infrastructure/production and a mapping method to assess the strengths and weaknesses of the country's transport infrastructure.

2. Literature review

The classical location theory emphasized the role of transport costs as a determinant of economic activity location (Weber, 1928; Moses, 1958; Alonso, 1964). The New Economic Geography (NEG) also highlights the role of transport costs as a location factor in imperfect competition and different degrees of interregional labour mobility (Fujita et al., 1999; Fujita & Thisse, 2002). Although, the theoretical basis for proving an 'umbrella' research hypothesis can be the macroeconomic theory of endogenous growth (Ferrari et al., 2019a) with its developed framework in which public infrastructure (including transport infrastructure) can be defined as a source of economic growth through its contribution to technical changes (Aschauer, 1990; Hulten & Schwab, 1991; Munnell, 1992; Garcia-Mila & McGuire, 1992) or smart technological changes, following the concept of intelligent transport (Chen & Silva, 2021), the innovative transportation system (Aamir et al., 2019) or smart transportation infrastructure (Ushakov et al., 2022).

Decision-makers have widely used investments in transport infrastructure to encourage economic growth, particularly during periods of economic downturn. There has been extensive research on the linkage between transport infrastructure and economic performance since the late 1980s, characterized by widely varying evidence (Melo et al., 2013). Following a break in popularity in the 1990s, industrial policy is again capturing attention worldwide as a driver of economic and broader societal goals. This is especially true in lower-income countries, where industrialization is still a crucial driver of economic growth (Yong, 2021), and the industrial past and industrial symbols well represent the present and are a matter of pride and collective identity for the residents (Bole et al., 2022). Although today in these countries, there is a positive trend of the emergence in the first place of the specific gravity and growth rate of engineering services, which generally corresponds to the direction of transition towards the post-industrial economy with its emphasis on services for all the sectors (Orynbassarova et al., 2019).

Some other studies also show trends in the shift from landscapes of production to landscapes of consumption, which need another type and quality of transport infrastructure. For example, American researcher Dwight Hines focused on the relevant inter- and intra-class-based dynamics of an ongoing capitalist-Modernity in the contemporary American West as a result of the transition from the prior dominance of a regime of production/consumption of commodities/natural resources to the increasing ascendancy of the

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production/consumption of 'experiences' (Dwight Hines, 2011). This process of 'rural gentrification' (Dwight Hines, 2011) facilitates the transition of rural areas from production to consumption landscapes with changing demands on transport infrastructure.

Latvian researchers-transport economists Skorobogatova and Kuzmina-Merlino (2017) state that there is a mutual connection between the quality of transport infrastructure and the country's macroeconomic performance. Developed transport infrastructure gives additional benefits through specific macroeconomic drivers of productivity. Therefore, the analysis of the interaction between transport infrastructure and the economy, as well as the measurement of the effect of this interaction, is a vital issue in the context of the implementation of the Strategic Development Plan Latvia 2030 adopted by the government of Latvia (Skorobogatova & Kuzmina-Merlino, 2017). Thus, transport plays and will continue to play an important economic role. Its role in Central and Eastern Europe has changed in adjusting the economies to the EU structures (Boruch, 2014). The studies of Latvian economists show how the development of the transport infrastructure of Latvia influenced the country's economic growth (Skorobogatova & Kuzmina-Merlino, 2017), mainly how investment in transport infrastructure affects the Latvian economic growth, which is measured by the GDP, as well as trade relations with foreign partners, especially with Poland (Boruch, 2014).

Latvian economists have done a lot to create a conceptual framework for defining the notion of transport infrastructure and developing a methodology for its study. Thus, Skorobogatova and Kuzmina-Merlino and their co-authors highlighted the role of the transportation industry in the economic development of Latvia, analyzed the notion of transport infrastructure as an essential part of the state transport system and estimated the approaches to the measurement of 'the transport infrastructure development performance' used in the global research space (Skorobogatova & Kuzmina-Merlino, 2017; Kotane & Kuzmina-Merlino, 2017; Kuzmina-Merlino et al., 2018). They focused on the necessity for the development of a methodology of measuring 'the transport infrastructure development performance' that should be applied systemically and that would be generally helpful to all responsible people making transportation-related decisions (Skorobogatova & Kuzmina-Merlino, 2017).

In the global scientific literature, there are two approaches to conceptual understanding transport infrastructure and production in a territory – the traditional narrow approach and the innovative broader approach. The following table presents them.

Table 1. Approaches to conceptual understanding of transport infrastructure and production in a territory

Approaches to conceptual understanding	Transport infrastructure	Production
Traditional narrow understanding	Infrastructure for air transport, rail transport, road transport, and water transport (as part of the global competitiveness of a territory)	Industrial production, which refers to the output of industrial establishments and covers sectors such as mining, manufacturing, electricity, gas and steam and air-conditioning
Innovative wider understanding	Trade- and transport-related infrastructure: ports, airports, roads, rail, warehousing/transloading and relevant ICT (as part of the logistics performance of a territory)	Gross Domestic Product (GDP) is the overall production in the territory, including IT and financial services, etc.

Source: elaborated by the authors based on Boruch, 2014; Grzelakowski, 2014; Skorobogatova & Kuzmina-Merlino, 2017; Jaramillo et al., 2018; Schwab, 2019; Orynbassarova et al., 2019; Komarova et al., 2022.

An analysis of the scientific literature shows that recent studies offer general approaches to conceptualizing transport infrastructure and production in a territory (Table 1). Still, there needs to be a detailed empirical interpretation of developed/underdeveloped transport infrastructure and territorial production, which is necessary to measure the state of development of transport infrastructure and production in a territory. The authors will fill this gap in the next section of the article, which describes the research methodology used in this particular study

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for the empirical interpretation of the concepts of developed transport infrastructure and developed production and their measurement in a territory.

3. Research methodology

To empirically prove a positive influence of the developed transport infrastructure on the development of production, it is necessary to choose and argue the methodological approach for the empirical interpretation of transport infrastructure and production in general and empirical interpretation and measurement of the state of development of transport infrastructure and production in particular.

In the global analytical literature, different approaches are implemented to empirically interpret transport infrastructure and measure the state of transport infrastructure development (Table 2). The most famous are as follows (Skorobogatova & Kuzmina-Merlino, 2017):

- Measuring the state of development of transport infrastructure based on the calculation of the Global Competitiveness Index (GCI), which the World Economic Forum developed;
- Measuring the state of transport infrastructure development based on evaluating the Logistics Performance Index (LPI), which the World Bank developed.

The Global Competitiveness Index (GCI) measures an economy's competitiveness level, defined as the set of institutions, infrastructure, policies, and factors determining an economy's productivity level (Schwab, 2019). Measurement of the state of transport infrastructure development is one of the parts of the total evaluation of the GCI. In turn, the Logistics Performance Index (LPI) analyses countries' differences in customs procedures, logistics costs and the quality of the trade- and transport-related infrastructure (Jaramillo et al., 2018). One more approach to empirically interpret transport infrastructure and measure the state of its development is based on the Territory Transport Development Index (TTDI) developed by Latvian economists (Komarova et al., 2022).

Table 2. Approaches to empirical interpretation of the transport infrastructure in the territory

Within the Global Competitiveness Index (GCI)	Within the Logistics Performance Index (LPI)	Within the Territory Transport Development Index (TTDI)
The 2nd pillar – Infrastructure (0–100) – involves the sub-pillar – Transport infrastructure (0–100) – with the following components: 2.01 Road connectivity 2.02 Quality of road infrastructure 2.03 Railroad density per 1000 km^2 2.04 Efficiency of train services 2.05 Airport connectivity 2.06 Efficiency of air transport services 2.07 Liner shipping connectivity 2.08 Efficiency of seaport services	The 2nd component – Infrastructure – measures the quality of trade- and transport-related infrastructure, rated from "very low" (1) to "very high" (5)	The 3rd component of the Index is the quality of transport infrastructure (1–7 best) in a territory, including:* - quality of road infrastructure - quality of railroad infrastructure - quality of port infrastructure - quality of air transport infrastructure

* The authors exclude one element, 'road connectivity', from the quality of transport infrastructure of the TTDI (Komarova et al., 2022).
Source: elaborated by the authors based on Jaramillo et al. 2018; Schwab, 2019; Komarova et al., 2022.

Based on the above analysis of the global and local research practice, the authors identify the following measurement tools for the development of transport infrastructure in a territory:

- Evaluation of transport infrastructure using the Global Competitiveness Index (GCI), which was developed by the World Economic Forum (Schwab, 2019);
- evaluation of the supply chain service delivery using the Logistics Performance Index (LPI), which was developed by the World Bank (Jaramillo et al., 2018);

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- evaluation of the overall quality of transport infrastructure using the Territory Transport Development Index (TTDI) developed by Latvian economists (Komarova et al., 2022).

Cigu et al. (2018) developed one more measurement tool for developing transport infrastructure – the Index of transport infrastructure. However, the authors will not use it within this study due to this Index's extensive set of indicators. According to the authors of this study, some indicators of the Index of transport infrastructure (for example, cars per 1000 inhabitants, air transport of passengers and goods, etc. (Cigu et al., 2018)) cover the development of the transport industry as a whole rather than the development of transport infrastructure.

The approaches to the empirical interpretation of the transport infrastructure and measurement of the state of development of transport infrastructure based on the calculation of the Global Competitiveness Index (GCI), the Logistics Performance Index (LPI) and the Territory Transport Development Index (TTDI), applied at the international level, characterize the overall situation in a particular country and in a specific aspect; it is assessed in the context of globalization and allows tracing changes over time. In the framework of this study, the authors will measure the state of development of transport infrastructure of the EU countries based on the GCI, the LPI and the TTDI and analyze results in a comparative way only within the EU countries. This means that the state of development (developed / underdeveloped) of transport infrastructure will be evaluated relative to the mean state of development of transport infrastructure of the EU countries. For example, suppose country A has an underdeveloped transport infrastructure. In that case, this is true within the EU, in relation to other EU countries, but not concerning other countries (for example, African countries).

As for the state of development of production in a territory, the following main approaches to its conceptual understanding are in the global economic space (Table 1):

- Traditional narrow understanding: industrial production, which refers to the output of industrial establishments and covers sectors such as mining, manufacturing, electricity, gas and steam and air-conditioning (Boruch, 2014; Grzelakowski, 2014);
- innovative wider understanding: the Gross Domestic Product (GDP) as the overall production in the territory, including IT and financial services, etc. (Skorobogatova & Kuzmina-Merlino, 2017; Orynbassarova et al., 2019).

Thus, the measurement tools/techniques for the development of production are as follows: (1) evaluation of production based on the calculation of industrial output, using the indicator of real output in the manufacturing, mining, electric, and gas industries (NationMaster.com, 2023); (2) evaluation of production based on broader approach and calculation of total output of the territorial economy, using the Gross Domestic Product (GDP) (Schwab, 2019).

The final methodological question to be answered in this study is the following: what does 'developed' mean in relation to transport infrastructure and production? When can we say a country's transport infrastructure/production is developed or undeveloped? This study will use a simple method of means, i.e. the transport infrastructure/production in a country will be considered developed (within the EU) if its state of development is above the EU mean, and vice versa, the transport infrastructure/production in a country will be considered underdeveloped (within the EU) if its state of development is below the average across EU countries. To obtain more stable results, the authors will test all five of the above tools for measuring the development of transport infrastructure/production in a territory.

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4. Results and discussion

Table 3 presents the results of measuring transport infrastructure development in the EU countries based on the sub-pillar of transport infrastructure, including the 2nd pillar 'Infrastructure' of the Global Competitiveness Index (GCI).

Table 3. Measurement of the state of development of transport infrastructure in a territory, the Global Competitiveness Index (GCI), n = 27* EU countries, scores,** 2019

EU countries	Components of the transport infrastructure, included in the 2nd pillar, 'Infrastructure' of the GCI								Common transport infrastructure
	2.01***	2.02	2.03	2.04	2.05	2.06	2.07	2.08	
Austria	81.9	83.5	100.0	71.1	65.3	70.7	-	44.3	78.7
Belgium	90.9	56.4	100.0	51.5	62.0	76.7	91.1	76.0	75.6
Bulgaria	76.6	40.2	92.8	35.1	49.0	57.5	6.8	55.4	51.7
Croatia	78.6	76.7	100.0	23.9	55.2	62.6	38.4	61.0	62.1
Cyprus	68.7	67.7	No railroad		50.9	68.7	19.5	55.0	55.1
Czechia	92.2	48.5	100.0	58.3	56.5	67.5	-	36.6	70.5
Denmark	86.6	76.2	100.0	59.1	66.3	79.4	58.5	79.4	75.7
Estonia	87.0	61.4	59.4	60.9	33.3	60.0	7.2	76.1	55.7
Finland	91.6	71.0	48.7	75.6	59.4	88.3	13.4	89.5	67.2
France	96.6	73.9	100.0	65.9	95.8	74.9	84.0	69.4	82.6
Germany	95.1	71.7	100.0	65.3	100.0	74.5	97.1	70.6	84.3
Greece	75.8	60.7	43.4	33.5	77.2	72.6	59.4	62.5	60.6
Hungary	86.2	50.3	100.0	47.4	52.5	59.7	-	35.9	66.0
Ireland	88.4	56.7	68.5	49.3	68.1	74.7	10.7	66.7	60.4
Italy	85.9	56.8	100.0	52.0	97.1	65.4	67.2	61.1	73.2
Latvia	89.2	43.0	74.8	60.3	40.1	77.5	8.1	65.3	57.3
Lithuania	89.9	62.8	76.3	59.6	36.1	64.9	21.0	63.1	59.2
Luxembourg	71.3	75.6	100.0	66.4	37.8	77.0	-	57.2	71.4
Netherlands	89.0	90.5	100.0	78.5	77.0	89.9	98.0	90.8	89.2
Poland	88.0	55.2	100.0	48.4	64.7	63.9	63.1	58.8	67.8
Portugal	94.2	83.2	69.5	54.0	72.0	67.2	65.1	64.6	71.2
Romania	79.3	32.6	100.0	30.3	54.5	59.7	29.8	49.1	54.4
Slovakia	83.5	49.8	100.0	50.1	27.5	46.3	-	35.6	59.5
Slovenia	74.3	65.8	100.0	35.5	30.4	59.3	39.3	61.6	58.3
Spain	100.0	78.4	77.9	72.9	100.0	76.9	90.1	73.0	83.6
Sweden	95.9	71.9	59.4	49.3	66.9	78.6	59.7	71.3	69.1
United Kingdom	91.3	64.4	100.0	55.2	100.0	72.2	95.6	69.2	81.0
Mean	86.2	63.9	87.3	54.2	62.8	69.9	51.1	62.9	68.2

* In 2019, the United Kingdom was the EU member state; Malta is not included due to its small territory.
** Scores are on a 0 to 100 scale, where 100 represents the optimal situation or 'frontier'.
*** Components of the transport infrastructure, included in the 2nd pillar 'Infrastructure' of the GCI:
2.01 Road connectivity
2.02 Quality of road infrastructure
2.03 Railroad density
2.04 Efficiency of train services
2.05 Airport connectivity
2.06 Efficiency of air transport services
2.07 Liner shipping connectivity
2.08 Efficiency of seaport services
Source: compiled by the authors based on Schwab, 2019.

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As noted above, within the research methodology, the EU countries with developed transport infrastructure scored above the mean, and the EU countries with underdeveloped transport infrastructure – scored below the mean. According to the GCI, the following table classifies the EU countries with developed and underdeveloped transport infrastructure. Also, it identifies those components of the transport infrastructure which are developed, intermediate or underdeveloped in each particular country of the EU.

Table 4. EU countries with developed and underdeveloped transport infrastructure according to the Global Competitiveness Index (GCI), n = 27 EU countries, 2019

Type of transport infrastructure in the territory	Road transport infrastructure (2.01 + 2.02)	Rail transport infrastructure (2.03 + 2.04)	Air transport infrastructure (2.05 + 2.06)	Sea transport infrastructure (2.07 + 2.08)	Common transport infrastructure
Developed transport infrastructure (above the mean)	Denmark, Finland, France, Germany, Netherlands, Portugal, Spain, Sweden, United Kingdom	Austria, Czechia, Denmark, France, Germany, Luxembourg, Netherlands	Austria, Denmark, France, Germany, Greece, Ireland, Netherlands, Spain, Sweden, United Kingdom	Belgium, Denmark, France, Germany, Netherlands, Portugal, Spain, Sweden, United Kingdom	Austria, Belgium, Czechia, Denmark, France, Germany, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom
Intermediate, i.e. one of the two indicators is above the mean; the other is below the mean	Austria, Belgium, Croatia, Cyprus, Czechia, Estonia, Ireland, Latvia, Lithuania, Luxembourg, Slovenia	Belgium, Bulgaria, Croatia, Estonia, Finland, Hungary, Italy, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia, Spain, United Kingdom	Belgium, Finland, Italy, Latvia, Luxembourg, Poland, Portugal	Estonia, Finland, Greece, Ireland, Italy, Latvia, Lithuania, Poland	-
Underdeveloped transport infrastructure (below the mean)	Bulgaria, Greece, Hungary, Italy, Poland, Romania, Slovakia	Greece, Ireland, Portugal, Sweden	Bulgaria, Croatia, Cyprus, Czechia, Estonia, Hungary, Lithuania, Romania, Slovakia, Slovenia	Austria, Bulgaria, Croatia, Cyprus, Czechia, Hungary, Luxembourg, Romania, Slovakia, Slovenia	Bulgaria, Croatia, Cyprus, Estonia, Finland, Greece, Hungary, Ireland, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia

Source: compiled by the authors based on the data from Table 3.

As Table 4 shows, the transport infrastructure of the 14 EU countries can be considered underdeveloped – generally, these are the countries of Central, Eastern and Southern Europe, including Latvia. However, Finland and Ireland, the countries of Northern and Western Europe, are also included in the list of countries with underdeveloped transport infrastructure – Finland due to relatively low (below the mean in the EU) railroad density, poor airport connectivity, and liner shipping connectivity (Table 3), Ireland due to relatively low quality of road infrastructure, low railroad density, low efficiency of train services and poor liner shipping connectivity (Table 3).

The following table presents a full mapping of the state of development of the transport infrastructure of Latvia (as an example) according to all components of the sub-pillar of transport infrastructure, including in the 2nd pillar, 'Infrastructure' of the GCI.

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Table 5. Mapping of the state of development of transport infrastructure of Latvia according to the Global Competitiveness Index (GCI), 2019

Strengths (above the mean)	Weaknesses (below the mean)
2.01 Road connectivity	2.02 Quality of road infrastructure
2.04 Efficiency of train services	2.03 Railroad density
2.06 Efficiency of air transport services	2.05 Airport connectivity
2.08 Efficiency of seaport services	2.07 Liner shipping connectivity
State of development of transport infrastructure	
Road transport infrastructure (2.01 + 2.02)	Intermediate, i.e. one of the two indicators is above the mean; the other is below the mean
Rail transport infrastructure (2.03 + 2.04)	Intermediate
Air transport infrastructure (2.05 + 2.06)	Intermediate
Sea transport infrastructure (2.07 + 2.08)	Intermediate
Common transport infrastructure	Underdeveloped, i.e. below the mean

Source: compiled by the authors based on the data from Tables 3 and 4.

As Table 5 shows, Latvia occupies the intermediate position in all components of the sub-pillar of transport infrastructure, including the 2nd pillar, 'Infrastructure' of the GCI. This means that one of the two indicators of each component is above the mean, and the other is below the mean. For example, Latvia is developed in terms of road connectivity but underdeveloped in terms of the quality of road infrastructure; it is underdeveloped in terms of railroad density but set in terms of the efficiency of train services, etc. (Tables 3 and 4). This mapping method allows us to assess the strengths and weaknesses of the country's transport infrastructure. Latvia's transport infrastructure is generally considered underdeveloped, as its overall development is below the EU average.

Table 6 presents the results of measuring transport infrastructure development in the EU countries based on evaluating the quality of trade- and transport-related infrastructure covered by the 2nd component 'Infrastructure' of the Logistics Performance Index (LPI).

Table 6. Measurement of the state of development of transport infrastructure in a territory, the Logistics Performance Index (LPI), n = 27 EU countries, scores,* 2019

EU countries	Quality of trade- and transport-related infrastructure covered by the 2nd component, 'Infrastructure' of the LPI	Developed transport infrastructure (above the mean)	Underdeveloped transport infrastructure (below the mean)
Austria	4.18	Austria	-
Belgium	3.98	Belgium	-
Bulgaria	2.76	-	Bulgaria
Croatia	3.01	-	Croatia
Cyprus	2.89	-	Cyprus
Czechia	3.46	-	Czechia
Denmark	3.96	Denmark	-
Estonia	3.10	-	Estonia
Finland	4.00	Finland	-
France	4.00	France	-
Germany	4.37	Germany	-
Greece	3.17	-	Greece
Hungary	3.27	-	Hungary
Ireland	3.29	-	Ireland
Italy	3.85	Italy	-
Latvia	2.98	-	Latvia
Lithuania	2.73	-	Lithuania
Luxembourg	3.63	Luxembourg	-
Netherlands	4.21	Netherlands	-

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Poland	3.21	-	Poland
Portugal	3.25	-	Portugal
Romania	2.91	-	Romania
Slovakia	3.00	-	Slovakia
Slovenia	3.26	-	Slovenia
Spain	3.84	Spain	-
Sweden	4.24	Sweden	-
United Kingdom	4.03	United Kingdom	-
Mean	3.50	-	-

* Rated from "very low" (1) to "very high" (5).
Source: compiled by the authors based on Jaramillo et al., 2018.

As Table 6 shows, LPI scores of the quality of trade- and transport-related infrastructure are also relatively low in Central, Eastern and Southern Europe countries, which generally have underdeveloped transport infrastructure compared to the countries of Northern and Western Europe. The following table presents the results of measuring the state of transport infrastructure development in the EU countries based on evaluating transport infrastructure quality using the components included in the Territory Transport Development Index (TTDI).

Table 7. Measurement of the state of development of transport infrastructure in a territory, the Territory Transport Development Index (TTDI), n = 27 EU countries, scores,* 2019

EU countries	Components of the quality of transport infrastructure				Overall quality of transport infrastructure**
	Quality of road infrastructure	Quality of railroad infrastructure	Quality of port infrastructure	Quality of air transport infrastructure	
Austria	6.0	5.3	3.7	5.2	5.1
Belgium	4.4	4.1	5.6	5.6	4.9
Bulgaria	3.4	3.1	4.3	4.5	3.8
Croatia	5.6	2.4	4.7	4.8	4.4
Cyprus	5.1	No railroad	4.3	5.1	4.8
Czechia	3.9	4.5	3.2	5.0	4.2
Denmark	5.6	4.5	5.8	5.8	5.4
Estonia	4.7	3.1	5.6	4.6	4.5
Finland	5.4	5.0	5.2	5.5	5.3
France	5.3	5.5	6.4	6.3	5.9
Germany	5.3	4.9	5.2	5.5	5.2
Greece	4.6	3.0	4.8	5.4	4.5
Hungary	4.0	3.8	3.2	4.6	3.9
Ireland	4.4	4.0	5.0	5.5	4.7
Italy	4.4	4.1	4.7	4.9	4.5
Latvia	3.6	4.6	4.9	5.7	4.7
Lithuania	4.8	4.6	4.8	4.9	4.8
Luxembourg	5.5	5.0	4.4	5.6	5.1
Netherlands	6.4	5.7	6.4	6.4	6.2
Poland	4.3	3.9	4.5	4.8	4.4
Portugal	6.0	4.2	4.9	5.0	5.0
Romania	3.0	2.8	3.9	4.6	3.6
Slovakia	4.0	4.0	3.1	3.8	3.7
Slovenia	4.9	3.1	4.7	4.6	4.3
Spain	5.7	5.4	5.4	5.6	5.5
Sweden	5.3	4.0	5.3	5.7	5.1
United Kingdom	4.9	4.3	5.2	5.3	4.9
Mean	4.8	4.2	4.8	5.2	4.8

* Scores are on a 1 to 7 scale, where 7 represents the optimal situation or 'frontier'.
** The arithmetic mean of the components' values of the quality of transport infrastructure in a territory.
Source: calculated and compiled by the authors based on Komarova et al., 2022.

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Table 7 shows the scores of the EU countries for the components of the quality of transport infrastructure in a territory covered by the TTDI: (1) quality of road infrastructure; (2) quality of railroad infrastructure; (3) quality of port infrastructure; (4) quality of air transport infrastructure. According to the research methodology, the EU countries with developed transport infrastructure scored above the mean, and the EU countries with underdeveloped transport infrastructure – scored below the mean.

The following table classifies the EU countries with developed and underdeveloped transport infrastructure according to the TTDI. Also, it identifies those components of the quality of transport infrastructure which are developed or underdeveloped in each particular country of the EU.

Table 8. EU countries with developed and underdeveloped transport infrastructure according to the Territory Transport Development Index (TTDI), n = 27 EU countries, 2019

Type of transport infrastructure	Quality of road infrastructure	Quality of railroad infrastructure	Quality of port infrastructure	Quality of air transport infrastructure	Overall quality of transport infrastructure
Developed transport infrastructure (above the mean)	Austria, Croatia, Cyprus, Denmark, Finland, France, Germany, Luxembourg, Netherlands, Portugal, Slovenia, Spain, Sweden, United Kingdom	Austria, Czechia, Denmark, Finland, France, Germany, Latvia, Lithuania, Luxembourg, Netherlands, Portugal, Spain, United Kingdom	Belgium, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Latvia, Lithuania, Netherlands, Portugal, Spain, Sweden, United Kingdom	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Latvia, Luxembourg, Netherlands, Spain, Sweden, United Kingdom	Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Lithuania, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom
Underdeveloped transport infrastructure (below the mean)	Belgium, Bulgaria, Czechia, Estonia, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Poland, Romania, Slovakia	Belgium, Bulgaria, Croatia, Estonia, Greece, Hungary, Ireland, Italy, Poland, Romania, Slovakia, Slovenia, Sweden	Austria, Bulgaria, Croatia, Cyprus, Czechia, Hungary, Italy, Luxembourg, Poland, Romania, Slovakia, Slovenia	Bulgaria, Croatia, Cyprus, Czechia, Estonia, Hungary, Italy, Lithuania, Poland, Portugal, Romania, Slovakia, Slovenia	Bulgaria, Croatia, Czechia, Estonia, Greece, Hungary, Ireland, Italy, Latvia, Poland, Romania, Slovakia, Slovenia

Source: compiled by the authors based on the data from Table 7.

As Table 8 shows, the transport infrastructure of the 13 EU countries can be considered underdeveloped according to its quality. As with the case with the GCI, these are preferably the countries of Central, Eastern and Southern Europe countries, including Latvia. However, Finland's transport infrastructure measured by the TTDI (and the LPI (Table 6), as opposed to the GCI) is considered as developed. As for Ireland, this remains the only country in Western Europe, which is included in the list of countries with underdeveloped transport infrastructure (also according to the LPI (Table 6)) due to the relatively low quality of road and railroad infrastructure (Table 8).

The following table presents a complete mapping of the state of development of the transport infrastructure of Latvia (as an example) according to all components of the quality of transport infrastructure covered by the TTDI.

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Table 9. Mapping of the state of development of transport infrastructure of Latvia according to the Territory Transport Development Index (TTDI), 2019

Strengths (above the mean)	Weaknesses (below the mean)
Quality of railroad infrastructure	Quality of road infrastructure
Quality of port infrastructure	-
Quality of air transport infrastructure	-
State of development of transport infrastructure	
Quality of road infrastructure	Underdeveloped transport infrastructure
Quality of railroad infrastructure	Developed transport infrastructure
Quality of port infrastructure	Developed transport infrastructure
Quality of air transport infrastructure	Developed transport infrastructure
Overall quality of transport infrastructure	Underdeveloped transport infrastructure

Source: compiled by the authors based on the data from Tables 7 and 8.

As Table 9 shows, Latvia generally has an underdeveloped transport infrastructure, and this result was also for the GCI and the LPI. Interestingly, this result is due only to the shallow quality of the road infrastructure – 3.6 in Latvia versus 4.8 on average in the EU (Table 7). However, all other types of transport infrastructure in Latvia are considered developed.

Thus, the results of the assessment of transport infrastructure in the EU countries are generally similar when using three different measurement tools – the GCI, the LPI and the TTDI. For example, Latvia has an underdeveloped transport infrastructure in all three indices. The situation is the same for assessments of the state of development of most EU countries' transport infrastructure in a particular country is developed, then in most cases, all three indices indicate this; if underdeveloped, this is also usually indicated by all indexes. As for Latvia, the results obtained differ from those of previous studies, which show that the business environment in Latvian regional towns has a developed multimodal transport network (Latviete, 2010).

The following two tables present the results of measuring the state of development of production in the EU countries based on the calculation of industrial output, using the indicator of real output in the manufacturing, mining, electric, and gas industries (Table 10), as well as based on the calculation of total output of the territorial economy, using the GDP (Table 11).

Table 10. Measurement of the state of development of territorial production, the industrial output, n = 27 EU countries, USD per capita, 2019

EU countries	Industrial production in the territory, measured by the real output in the manufacturing, mining, electric, and gas industries	Developed production (above the mean)	Underdeveloped production (below the mean)
Austria	10,224.8	Austria	-
Belgium	7,569.7	Belgium	-
Bulgaria	900.3	-	Bulgaria
Croatia	2,198.3	-	Croatia
Cyprus	2,062.9	-	Cyprus
Czechia	4,057.6	-	Czechia
Denmark	9,989.1	Denmark	-
Estonia	2,507.3	-	Estonia
Finland	9,439.6	Finland	-
France	6,307.3	France	-
Germany	9,082.7	Germany	-
Greece	3,754.3	-	Greece
Hungary	2,638.5	-	Hungary
Ireland	15,070.1	Ireland	-
Italy	7,253.0	Italy	-

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Latvia	1,347.0	-	Latvia
Lithuania	2,267.5	-	Lithuania
Luxembourg	11,397.9	Luxembourg	-
Netherlands	8,296.0	Netherlands	-
Poland	2,141.9	-	Poland
Portugal	3,690.8	-	Portugal
Romania	1,404.6	-	Romania
Slovakia	2,530.9	-	Slovakia
Slovenia	5,099.6	-	Slovenia
Spain	6,842.2	Spain	-
Sweden	9,760.0	Sweden	-
United Kingdom	8,482.7	United Kingdom	-
Mean	5,789.5	-	-

Source: compiled by the authors based on NationMaster.com, 2023.

Table 11. Measurement of the state of development of territorial production, the Gross Domestic Product (GDP), n = 27 EU countries, USD per capita, 2019

EU countries	Overall production in the territory, including IT and financial services, etc., measured by the GDP per capita	Developed production (above the mean)	Underdeveloped production (below the mean)
Austria	51,509.0	Austria	-
Belgium	46,724.3	Belgium	-
Bulgaria	9,267.4	-	Bulgaria
Croatia	14,815.9	-	Croatia
Cyprus	28,339.9	-	Cyprus
Czechia	22,850.3	-	Czechia
Denmark	60,692.4	Denmark	-
Estonia	22,989.9	-	Estonia
Finland	49,845.0	Finland	-
France	42,877.6	France	-
Germany	48,264.0	Germany	-
Greece	20,407.9	-	Greece
Hungary	15,923.8	-	Hungary
Ireland	76,098.6	Ireland	-
Italy	34,260.3	-	Italy
Latvia	18,032.0	-	Latvia
Lithuania	19,143.4	-	Lithuania
Luxembourg	114,234.2	Luxembourg	-
Netherlands	53,106.4	Netherlands	-
Poland	15,430.9	-	Poland
Portugal	23,186.3	-	Portugal
Romania	12,285.2	-	Romania
Slovakia	19,581.6	-	Slovakia
Slovenia	26,234.3	-	Slovenia
Spain	30,697.3	-	Spain
Sweden	53,873.4	Sweden	-
United Kingdom	42,558.0	United Kingdom	-
Mean	36,045.5	-	-

Source: compiled by the authors based on Schwab, 2019.

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The following table compares the estimates of the state of development of production based on the two measurement tools: the industrial output (Table 10) and the GDP (Table 11).

Table 12. Comparison of the state of development of production in a territory, the industrial output and the Gross Domestic Product (GDP), n = 27 EU countries, USD per capita, 2019

State of development of production in a territory	Measured by the industrial output per capita	Measured by the GDP per capita
Developed production (above the mean)	Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Spain, Sweden, United Kingdom	Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Luxembourg, Netherlands, Sweden, United Kingdom
Underdeveloped production (below the mean)	Bulgaria, Croatia, Cyprus, Czechia, Estonia, Greece, Hungary, Latvia, Lithuania, Poland, Portugal, Romania, Slovakia, Slovenia	Bulgaria, Croatia, Cyprus, Czechia, Estonia, Greece, Hungary, Italy, Latvia, Lithuania, Poland, Portugal, Romania, Slovakia, Slovenia, Spain

Source: compiled by the authors based on Tables 10 and 11 data.

Table 12 shows that the only difference between the set of the EU countries with developed and underdeveloped production measured by the industrial output per capita and by the GDP per capita is Italy and Spain, which are considered to have a developed production measured by the industrial output and underdeveloped production measured by the GDP. All other EU countries have developed or underdeveloped production, regardless of the measurement tool (Tables 10 and 11), and this situation is analogous to measuring the state of development of transport infrastructure.

As for Latvia, it has underdeveloped production in terms of industrial production per capita and GDP per capita (Tables 10 and 11), which is in line with the results of other studies. For example, Voronov concludes that most enterprises in Latvian towns, financed by local capital (usually up to 20,000 euros), cannot switch to high-value-added production, which requires considerable investment (over 100,000 euros) (Voronov, 2022). Therefore, the need for external investors, internal financial savings, and top specialists leads to the preponderance of mid and low-tech enterprises in regional towns. Most such businesses involved in construction, metalworking, woodworking, maintenance and services generate low value added (Voronov, 2022).

The approaches to the empirical interpretation of the transport infrastructure and measurement of the state of development of transport infrastructure based on the calculation of the GCI, the LPI and the TTDI, applied at the international level, cannot be applied within a country for measuring the productivity effects of transport infrastructure activity and for measuring the return on transport infrastructure investments. This is the main limitation of the research findings within this article. As mentioned in the Introduction to this article, in scientific space and Latvia, attempts are being made to solve this methodological weakness.

For example, the analysis of the spatial determinants of productivity in the regions of Great Britain introduced by Rice and Venables (Rice & Venables, 2004; Rice et al., 2006) can be mentioned here. They divided regional space into commuting zones (in relation to the cities – centres of the 'economic mass'), i.e. < 30-minute commuting zone, 30-40 minute commuting zone, 40-50 minute commuting zone, etc. In their research, they found that a robust and quantitatively important determinant of variations in productivity between NUTS3 regions of Great Britain is the proximity of each area to the centre of the 'economic mass' – the presence of a large population of working age within 80 minutes or less driving time (Rice & Venables, 2004; Rice et al., 2006). Thus, the concept of reachability of the territory – the time required to achieve the goal of relocation 'from door to door', using various types of relocation, including transport – was used for measuring the state of development of transport infrastructure in the mezo- and micro-territorial level. In Latvia, territorial reachability was used for measuring the state of development of transport infrastructure at the level of counties. To assess territorial

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reachability, Latvian researchers Niedole and Averyanov used the graphic-analytical method based on isochronograms (Niedole & Averyanov, 2011).

5. Conclusions

In global scientific practice, there are two approaches to conceptual understanding transport infrastructure and production in a territory – the traditional narrow approach and the innovative broader approach. According to the first one, transport infrastructure is understood traditionally as the infrastructure for air transport, rail transport, road transport, water and inland transport (as part of the global competitiveness of a territory), but the production – as an industrial production, which refers to the output of industrial establishments and covers sectors such as mining, manufacturing, electricity, gas and steam and air-conditioning. In turn, the innovative approach refers to the trade- and transport-related infrastructure: ports, airports, roads, rail, warehousing / translating and relevant ICT (as part of the logistics performance of a territory). As for production, this broader approach refers to the Gross Domestic Product (GDP) as the overall production in the territory, including IT and financial services, etc.

The assessment results of the state of transport infrastructure development in the EU countries are generally similar when using three different measurement tools – the GCI, the LPI and the TTDI. For example, Latvia has an underdeveloped transport infrastructure in all three indices. The situation is the same for assessments of the state of development of most EU countries' transport infrastructure in a particular country is developed, then in most cases, all three indices indicate this; if underdeveloped, this is also usually indicated by all indexes used. As for the state of development of production, the only difference between the set of the EU countries with developed and underdeveloped production measured by the industrial output per capita and by the GDP per capita in Italy and Spain, which are considered to have a developed production measured by the industrial output and underdeveloped production measured by the GDP. All other EU countries have developed or underdeveloped production, regardless of the measurement tool. For example, Latvia has underdeveloped production both in terms of industrial output and the GDP.

Thus, the results of this study show that, firstly, there are two main approaches to the conceptual understanding of transport infrastructure and production – traditional (narrower) and innovative (wider); secondly, developed transport infrastructure and developed products in the EU country are interpreted empirically with scores above the EU average, thirdly, almost all EU countries demonstrate a developed or underdeveloped transport infrastructure and production, regardless of their measurement tools, i.e. different measurement tools show nearly the same result. Based on the analysis of previous studies, the authors put forward a hypothesis that the priority for the economic development of the territory in the modern world is precisely the developed transport infrastructure, which, in turn, stimulates the growth of production, and not vice versa. However, this hypothesis cannot yet be tested using the data obtained in the present study.

The novelty of the obtained results lies in the empirical interpretation of the notions of transport infrastructure and production in a territory within the traditional and innovative approaches to conceptual understanding of transport infrastructure and production offered in the scientific literature. The authors' empirical interpretation of the transport infrastructure and territorial production is more relevant concerning the above notions than previous attempts (for example, such as the Index of transport infrastructure (Cigu et al., 2018)), and can be used by other researchers. Furthermore, the existing measurement tools are tested and compared. The results of this study, based on the use of various tools for measuring the state of development of transport infrastructure and production in the EU countries, can be used to implement policies in the transport and industrial sectors. The results obtained will also help the authors in the future, based on quantitative empirical data and case studies, to answer the ‘umbrella’ research question about what is a priority for the economic development of a territory: a developed transport infrastructure or a developed production, i.e. what is the priority for investments in the conditions of objectively limited resources? A limitation of this study is the macro-territorial level of analysis (especially regarding

transport infrastructure), which means that transport infrastructure development is empirically interpretable and measurable for countries as a whole rather than for their internal regions. However, attempts are being made to solve this methodological weakness in scientific space and Latvia.

In further research on the development of tools for measuring the state of development of transport infrastructure and production in a territory, it is necessary to pay attention to the internal regions of countries to identify the direction and nature of the relationship between the developed transport infrastructure and developed production in a territory at the mezzo-level. This is easier to implement in relation to output than transport infrastructure since tools for measuring the state of development of production in a territory, the industrial output and the GDP per capita are usually available for the countries' internal regions (Boronenko et al., 2014; Dauderstädt, 2021). Another important aspect for future research is that transport infrastructure must be viewed both as a whole and by the types of transport. Moreover, some traditionally industrial territories (countries or regions) in the Eastern and Central Europe faced falling industrial production and transition to the new smart specialization approach, which provides a better understanding of the region's specifics and the highest return on investment in innovation. As a result, some territories become more profitable to focus on applied research and transmit them into practice in relation to existing products and technological processes (Petrenko et al., 2019), but not on industrial production. Consequently, the purpose and type of transport infrastructure in such territories are also changing in a 'smart direction'.

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