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SPATIAL PATTERNS AND TIME-ACCESSIBILITY OF SUPPLIER NETWORK OF THE AUTOMOTIVE INDUSTRY IN SLOVAKIA

Jaroslav Rusnák¹  • Pavol Ďurček¹ • Milan Takáč¹ • Kristián Óvári²

¹Department of Economic and Social Geography Demography and Territorial Development
Comenius University in Bratislava
Mlynská dolina, 842 15 Bratislava: Slovak Republic
e-mails: jaroslav.rusnak@uniba.sk (corresponding author) • pavol.durcek@uniba.sk • takac28@uniba.sk

²Statistical Office of the SR
Lamačská cesta 3/C, 840 05 Bratislava: Slovak Republic
e-mail: kristian.ovari46@gmail.com

Abstract

The article deals with the spatial pattern of the supply network of the automotive industry according to the time-accessibility to four car assembly plants in Slovakia. Empirical results are anchored in the spatial concept of integrated periphery and theoretical framework of the nested structure. We obtained the data after a personal meeting with the General Secretary of the Association of the Automotive Industry in Slovakia. The database contains a list of 313 suppliers of different levels. We assume that with increasing distance from automobile assembly plants and decreasing level of the supply network, the geographical concentration of the supply network will become lower. Our results confirm the assumption that tier-1 suppliers are located closer to assembly plants with higher geographical concentration compared to bottom suppliers' levels. On the other hand, these spatial patterns change when we consider a regional production system of the automotive industry that reaches beyond the national territory scale (e.g., KIA) or a launch of a new car assembly plant (JLR) arriving into a developed environment with an existing network of suppliers.

Key words

Automotive industry • integrated periphery • nested structure • supply network • time-accessibility
• spatial pattern • Slovakia

Introduction

The automotive industry is a sector with huge potential to create jobs all around the world. About 8 million people are employed

directly in automobile production worldwide and further 12 million people are involved in selling and servicing vehicles (Dicken, 2011). Since the 1980s increasing global integration and internationalization of the

automotive industry has been manifested through the rising power of global suppliers and acceleration of outsourcing and capital offshoring to lower-cost peripheral locations (Sturgeon et al., 2008). The region of Central Europe (Czechia, Slovakia, Poland and Hungary, CE) has become attractive for foreign direct investment (FDI) thanks to similar factors endowments, proximity to Western European market, its automotive traditions (in the case of the Czechia and Poland), generous investment incentives and neoliberal reforms in the labour market (Pavlínek, 2002). Over 30 years, this region has become fully integrated into the global automobile production network. CE countries are integrated into the automotive industry of the EU in a similar way as Mexico is integrated into the US automotive industry. These newly emerging peripheral automotive production regions within global production networks are known as integrated peripheries (Brincks et al., 2018).

The automotive industry is essentially an assembly and a producer-driven industry (Dicken, 2011) consisting of a network of relationships between the car assembly plants, a few global suppliers of modules and a myriad of local suppliers of components or raw materials (Sturgeon & Lester, 2004). The transmitting of responsibilities and competencies to specialised suppliers has led to the formation of a supply network with a hierarchical structure: first-tier suppliers (tier-1), second-tier suppliers (tier-2) and third-tier suppliers (tier-3) (Pavlínek & Janák, 2007; Frigant & Layan, 2009). The supply network hierarchy consists of the fact that each of these suppliers can be located in different places and focused on performing specialized tasks with different added value in order to cut costs down. On the other hand, suppliers of different levels are often clustered in the vicinity of assembly plant. These changes in production management and logistics have opened a path to new production and organisational systems, so-called modular production (Frigant & Lung, 2002), which leads to increasing interaction and cooperation between car assembly plants and suppliers at various

scale level. Thus, the automotive industry has a specific nested geographical and organisational structure (Sturgeon et al., 2008).

A relatively great deal of attention is being devoted to global contexts in terms of the labour market and innovations (Brincks et al., 2018; Drahokoupil, 2020; Tripl et al., 2021), creating, enhancing and capturing value in regional production systems (Pavlínek et al., 2009; Pavlínek & Ženka, 2016; Ambroziak, 2018; Vlčková, 2018; Molnár et al., 2020) or intra-regional trade and export patterns (Molnár et al., 2015; Garcia and Paz, 2017; Micek et al., 2021). Less attention is paid to the local level (within countries), where regionally integrated local clusters are emerging. These are territorially embedded in the diverse political, social and cultural conditions of regional economies and have the potential to contribute to regional economic growth.

The aim of this paper is to identify the spatial pattern of the supply network of the Bratislava–Žilina auto corridor (Jacobs, 2017) among different levels of suppliers and four automobile companies (Volkswagen Slovakia – VWS, Peugeot-Citroen – PSA (currently Stellantis), Kia Motors – KIA, Jaguar Land Rover – JLR). Based on theoretical and empirical evidence, we assume that regional production systems have been formed through the modularisation of production, which forced suppliers of different levels (especially tier-1 suppliers) to create local clusters in the vicinity of assembly plants (Frigant & Lung, 2002; Schmitt & Van Biesebroeck, 2013). In this work we will attempt to answer two research questions: Are tier-1 suppliers on average localised closer to automotive assembly plants than tier-2 and tier-3 suppliers? Specifically, we will try to identify what the average time-accessibility from the car assembly plants of four automobile companies (VWS, Stellantis, KIA and JLR) within which at least 50% of suppliers are geographically concentrated according to the level of the supply network. We formulated the second research question as follows: how the geographical concentration of supply network changes depending on their time-accessibility to the car assembly plants?

We use the internal database of the Automotive Industry Association of the Slovak Republic, which, we obtained after a personal meeting with the General Secretary of the Association of the Automotive Industry. The paper's innovativeness lies in the emphasis on the analysis of time-accessibility of 313 firms with application of Google Maps online distance measuring tools. Thus, the article complements and expands previous knowledge gained through qualitative research (e.g. Pavlínek, 2016; 2018, 2020).

The paper is structured as follows: in section two, we discuss the spatial concept of integrated periphery with a focus on its dynamic expressed by concept of spatio-temporal fix with an emphasis on the CE region, and in section three, we look at the concept of the nested structure of the automotive industry with a focus on regional integrated local clusters and modular production. In the next section, we present a database and analytical methods for identifying and visualising spatial interactions. Then, in the final section we assess and discuss the results that identify the spatial framework of the automotive industry. These can serve the makers of the state's industrial policy when deciding on investment plans in support of foreign and domestic suppliers.

The global production network and dynamics of the integrated periphery of the automotive industry: Central Europe region

According to Mudambi (2008), in contemporary capitalism, transnational corporations (TNCs) consider two dimensions of strategic choice with respect to their value chain activities: control and location. Compared to the intangible and non-productive TNCs' activities, which generate high added value (research, design and marketing), (mass) production itself and assembly manufacturing contributes to the lowest value-added. TNCs maintain control over the high value-added activities and outsource or offshore low

value-added activities. The smiling curve theory shows the relationship between location and control of the value chain and explains why some activities are prone to delocalization and others are not. For this reason, TNCs concentrate non-manufacturing activities in core regions (usually in the country in which they are based) and relocate assembly manufacturing to integrated peripheries (Pavlínek, 2012).

According to Pavlínek (2018: 144-147), "(...) an integrated periphery refers to a dynamic low-cost (industrial) area that has been integrated in a core-based macroregional production network, which shares the following nine features: (1) geographic proximity to a large market; (2) export-oriented production; (3) dependence on foreign capital; (4) low labour costs; (5) specialization in a the mass production of standardized vehicles; (6) underdevelopment of automotive R&D; (7) flexible labour practices; (8) FDI friendly automotive industry state policies, and (9) membership in free trade agreement."

Since the collapse of socialism and the triumph of free-market capitalism (Jones, 2010), CE region has emerged as one of the most potential market spaces in Europe, also conceptualized as integrated periphery (Pavlínek, 2018). FDI have been considered a major force in the economic development of transition economies of CE (Pavlínek, 2004; Drahokoupil, 2008). The motivations of large automotive companies to invest in CE have been threefold. First, foreign investors seek both, a cheap and skilled labour force and the opportunity to gain access to local markets in the region (Havas, 1997; Domański & Lung, 2009). At the same time, the CE region is geographically proximate to a large western EU market. Second, foreign investors were aware of the industrial tradition of automotive sector in CE, which existed under state socialism. Pavlínek (2002: 1697) states that "VW has successfully pursued very different investment and development strategies in the Czech, Slovak, and Hungarian auto industries". Due to various industrial strengths, traditions, and supply networks, VW has implemented three transformation strategies:

embedded path-dependent transformations in Škoda plants in the Czech Republic, disembedded path-dependent transformations in VW Slovakia plant in Bratislava, and disembedded greenfield operations in Audi plant in Győr. Finally, national governments have attracted investors by generous investment incentives. Since the early 21. century, CE countries have engaged in the race to the bottom over automotive FDI (2006; Kolesár, 2006). Through FDI, TNCs search for new ways to enhance their own competitiveness (Dicken, 2011) and with increasing European economic integration through various forms of strategic coupling (McKinnon, 2012) to gain advantages and opportunities for value creation, enhance and capture (Henderson et al.; 2002; Coe et al., 2004; Pavlínek and Ženka, 2016).

Pavlínek (2018) used Harvey's concept of spatio-temporal fix (Harvey, 1982, 2010) to explain the dynamics of the uneven development of the global automotive industry in integrated peripheries. The essence of spatio-temporal fix lies in the fact that the capital seeks new territories where it can expect to make a profit. With increasing globalisation and European economic integration of the automotive industry, surplus capital is shifting from core regions to integrated peripheries with a surplus and cheap labour. However, this spatial process is only temporary. If the potential expressed as spatio-temporal fix (finding cheaper and more profitable places), institutional fix (liberal labour market conditions and state investment support coming to an end), technological fix (overly dense and antiquated transport infrastructure) and organisational fix (expensive implementation of new production systems, the possibility of management and control by foreign owners in the host country is limited) become exhausted, the production process is shifted to new integrated peripheries (Pavlínek, 2020).

The dynamic character of the integrated peripheries in Europe is reflected in the new international division of labour (Domański et al., 2008; Pavlínek, 2022), which includes: (1) traditional core areas of the automobile

industry in Western Europe (Britain, France, Italy, Germany, Sweden) (2) semi-peripheries as older integrated peripheries of the automobile industry (e.g. Belgium, Spain and Portugal) and (3) new integrated peripheries in Central Europe. The criterion for distinguishing between core, semi-periphery and periphery are trade relations, degree of foreign control and innovation capabilities (Pavlínek, 2022).

The dynamics of core-periphery relationships means that the high-road work model, typical of Europe's core automotive countries and characterised by high product quality, productivity and production volume, production organisation, increasing employee skills and high level of research and development expenditure, has been partly implemented in integrated peripheries countries, where the low-road work model, based on labour intensity and low added value of goods, prevailed (Domański & Gwosdz, 2009; Jürgens & Krzywdzinski, 2009; Lampon et al., 2016). Therefore, some traditional core areas (e.g. United Kingdom, Sweden) and older integrated peripheries (e.g. Belgium, Spain and Portugal) suffer from jobs losses, while countries of new integrated periphery (e.g. CE) record creating jobs in new-launched factories (Jacobs, 2019; Mordue & Sweeney, 2020; Pavlínek, 2020).

At the same time, the transfer of the low-road work model from the countries of the current integrated periphery (CE) to the low-cost countries of south-eastern Europe, such as Romania, Bulgaria, Ukraine and Serbia, is becoming more and more current. Discussions are emerging from the experience in North America, where since the end of the 1990s the competitive advantages of the Canadian automotive industry have declined with the growth of the Mexican automotive industry (Mordue & Sweeney, 2017). The trend of gradual relocation of production based on labour intensity and low value-added products to low-cost countries of south-eastern Europe has been confirmed by qualitative research based on 91 interviews with managers of foreign automotive subsidiaries in Czechia and Slovakia (Pavlínek, 2020). Between 2009-2015, "24% of the foreign

subsidiaries interviewed in Czechia and 26% in Slovakia already relocated parts of their production abroad, while 16% in Czechia and 21% in Slovakia were considering future relocations. On the other hand, the reason why foreign investors producing more complex components and modules operating at higher levels of supply networks are not considering relocating production from integrated peripheral countries is that labour cost differences between Western and Central Europe are still high (48% of the interviewed firms), and they take other factors, such as sunk costs, supplier relations, labour skills and proximity to the market into consideration" (Pavlínek, 2020: 533-534). These findings confirm that automakers are continually looking for more profitable places with lower costs, government subsidies and an abundant labour force, where they can introduce effective organizational and production systems in terms of spatio-temporal fix.

The nested structure of the automotive industry and modular of production: focus on the local cluster

The nested structure of automotive industry reflects the logic of geographical and organizational advantages emerging at multiple scale levels (Sturgeon et al., 2008). Global level is defined by buyer-supplier relationships, especially between automakers and their largest suppliers. Research and development in automotive industry is globally integrated and concentrated in a few design centres. Moreover, the global integration of mega suppliers was enhanced by a wave of mergers and acquisition in the 1990s (Frigant & Layan, 2009). The regional level is specific as it reaches beyond the national territory, and it includes the production of finished cars and a market of components within a production system where components flow between regions according to the supplier requirements of modular production. The regionally integrated production system, which

is characterised by a modular organisation with an emphasis on responsibility for the quality and speed of delivery requires well developed transport infrastructure (Klier & McMillen; 2015; Csíki et al., 2019). Just-in-time (JIT) and just in sequence (JIS) delivery system lead several suppliers of different levels to form a local clustering around assembly plants.

According to Frigant and Zumpe (2017), we can differentiate four reasons why automobile suppliers are aggregating into clusters: (1) new forms of production systems, like lean production, which use new logistic systems, such as JIT and JIS; (2) organisational learning effects in particular, when carmakers develop new forms of productive organisation; (3) the search for site-specific assets based on bargaining and cooperation relationships between regional institutions assets (competence, capacity, infrastructure, labour market regulations, incentives and taxation) and the needs of key actors in GPNs and (4) the reduction of coordination costs, in particular in a context of mutual learning (trust, conventions). A modular production process founded on the co-localisation of module manufacturers (particularly tier-1 suppliers) and vehicle assembly plants (Frigant & Lung, 2002) has led to the reorganisation of production and supplier roles into three supplier levels, which differ in the ability of suppliers to make and supply various complex parts, components and modules (Pavlínek & Janák, 2007; Frigant & Layan, 2009).

Tier-1 produce a macro-components, such as cockpits, seats, engines, transmissions and body panels, which are large, heavy and fragile. From the viewpoint of the countries of the integrated periphery, they are more internationalised (operating in the host country) (Pavlínek & Janák, 2007) and create and capture higher added value than lower-tier suppliers (Pavlínek & Ženka, 2016). They have acquired the most responsibilities in the field of research and development from the final manufacturers, which leads to long-term relationships between the assembly plant and tier-1 (Pavlínek, 2012). Delivering individualised

modules directly to the production line demands sophisticated logistics and synchronisation of their production at the required time and order. They are found in the vicinity of an assembly plant (Pavlínek & Janák, 2007), often inside or at the same site as a vehicle assembly plant, e.g. supplier parks (Larsson, 2002; Reichhart & Holweg, 2008). The difference lies in whether tier-1 delivers pre-assembled modules directly to the assembly line, which the manufacturer then installs, so-called industrial condominium, or the vehicle producer shifts these competencies (production) on tier-1 and its role is to coordinate production processes, so-called modular consortium (Frigant & Lung, 2002). They create various spatial forms in co-localisation with other levels of the supply chain, such as the hub-and-spoke industrial district, which is characterised by several large, vertically integrated firms operating in economies of scale, surrounded by lower tier suppliers, with which they maintain long-term cooperation and commercial contracts (Gwosdz & Micek, 2010), or the satellite platform of higher order (Ženka et al., 2017), which means that TNCs in the host country concentrate tier-1 branches, which in addition to production activities also develop non-manufacturing activities, including research and development with higher added value (Pavlínek, 2012). Similarly, meso-components (seat frames, gearboxes) produced by tier-2 are produced in high-volume factories in close vicinity to macro-components assembly units or directly to final assemblers (Frigant & Layan, 2009).

Conversely, TIER3 are less internationalized, and they generally produce less sophisticated and lower value-added standardized components and other simple parts (pipes, shock absorber) (Pavlínek & Ženka, 2016). The relationships between the assembly plant or TIER1 are based on short-term contracts, where the price of the product is crucial (Gerffi et al., 2005). Simple components or raw materials do not have to be supplied in the JIT mode. For this reason, they do not have to be located near assembly plants or TIER1, but

rather in regions with cheap labour (Frigant & Lung, 2002; Pavlínek & Janák, 2007; Pavlínek & Ženka, 2016). As a result, many suppliers of macro-components tend to be concentrated close to the final assembly plants due to close functional interdependences and storage areas minimization. At the same time, as they are global mega-suppliers, they want to be linked regionally with other levels of suppliers. Frigant and Zumpé (2017) claim that global mega-suppliers try to create economies of scale and scope via the design of meso-components from which different models of macro-components are built for special needs of the car assembly plant. Global mega-suppliers organise suppliers producing meso and simple components in the bottom levels of the pyramid. We can say that with the decreasing importance of the supply level (e.g. tier-3), the average distance from the final car manufacturers increases. Logistics costs seem to be less significant as a factor of low production costs in peripheral regions. In contrast, TIER1 suppliers, which use the JIS and JIT regimes are closer to assembly plants, locate in more competitive regional economies and local clusters, so they seek the benefits from agglomeration.

Data and methods

We use the internal database of the Automotive Industry Association of the Slovak Republic (AIA SR), which we obtained by a personal meeting with Ján Pribula, the General Secretary of the Association of the Automotive Industry. AIA SR provided a database that contains all registered firms that were part of the automotive supply chain in Slovakia as of 2018. The AIA SR database contains individual companies divided into three levels according to supplier-customer relations. The original database was made up of 326 suppliers that supply parts for final manufacturers or for other levels of suppliers. Moreover, additional 74 suppliers providing various services in the field of research and development, consulting, logistics or technical service are also part of the chain. The article works on a certain

part of the database; it works only with suppliers of parts in the manufacturing sector. The complexity of the supply chain comes from the fact that several suppliers do not supply exclusively to the automotive industry but also offer their product portfolio to other manufacturing sectors. Another limiting element of the database is the fact that some companies can simultaneously be tier-1, tier-2 and tier-3 suppliers. We have taken these facts into account when editing the database. In some cases, we found that a foreign company operates two, sometimes even three production plants located in different regions with one administrative headquarters (e.g. Adient, Faurecia, ZF Slovakia). This database was then enhanced by specific data published on the FinStat internet portal: (predominant, company-declared) branch specialisations according to SK NACE Rev. 2, the origin of the capital, year of registration. After a careful selection, we ultimately worked with a total number of 313 suppliers: 113 tier-1, 111 tier-2 and 89 tier-3 (Tab. 1).

To identify location and spatial interactions in the most accurate way possible,

we proceeded to determine the geographical coordinates of individual suppliers using Google Maps. We used these coordinates to calculate the distance between the suppliers and the assembly plants in kilometres. Figure 1 shows the spatial distribution of firms according to their position in the supply network. About 66% of suppliers are located within municipalities whose administrative areas are intersected by a highway or an expressway. This finding is consistent with previous work (Klier & McMillen, 2015; Csíki et al., 2019). Subsequently, we measured the time-accessibility in a real-world model of the road network, published in the work by Stanek et al. (2021). This road network model considers the speed limits of freight traffic, crossroads with the necessity to yield when driving, the permeability of some road sections and the resulting speed (curves, significant ascents or descents of the road). We paired the travel time between assembly plants and individual suppliers, which were geo-referenced using coordinates in the ArcGis 10.1 software, where we used the Network Analyst functionality and the specific tool New OD Cost

Table 1. Sample data according to selected attributes

Supplier	Latitude	Longitude	Municipality	id_	Supplier network	NACE	Ownership	Date of establishment
1. prešovská nástrojáreň, s.r.o.	49.016	21.263	Lubotice	518590	TIER3	25	1	1999
2J Antennas, s.r.o.	49.294	21.257	Bardejov	519006	TIER1	26	3	2005
Adient Seating Slovakia s.r.o., Trenčín	48.887	17.998	Trenčín	505820	TIER1	29	2	2004
Adient Seating Slovakia s.r.o., Žilina	49.230	18.737	Žilina	517402	TIER1	29	2	2004
Adient Slovakia s.r.o., Lučenec	48.315	19.675	Lučenec	511218	TIER1	29	2	2005
Akebono Brake Slovakia s. r. o.	48.889	17.996	Trenčín	505820	TIER2	29	2	2014
Alba Tooling & Engineering, s.r.o.	48.091	18.169	Šurany	503592	TIER3	22	2	2004
ALRO-SLOVAKIA s.r.o.	48.361	17.573	Trnava	506745	TIER3	25	2	2006
ANDRITZ Slovakia s.r.o.	48.922	21.890	Humenné	520004	TIER3	25	2	2005
ANTOLIN TRNAVA, s.r.o.	48.389	17.568	Trnava	506745	TIER1	29	2	2015

Note: Ownership: 1 – domestic, 2 – foreign, 3 – mixed.

Source: Own elaboration according to AIA SR, 2018

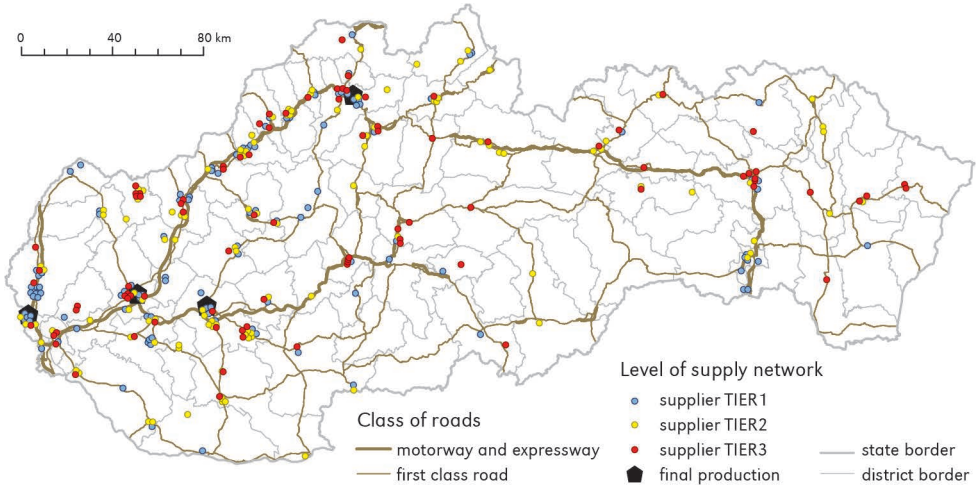


Figure 1. Spatial distribution of automotive firms in Slovakia based on their position in the supplier hierarchy in 2018

Source: Own elaboration according to AIA SR, 2018.

Matrix. Compared to daily travel-to-work flows, where Euclidean metrics are used to capture different modes of transport (Halás et al., 2014), the time-accessibility model seems more relevant, because the transport of components is realized by freight transport along existing highways and expressways.

To show the spatial patterns of firms at individual supplier levels around the assembly plants, we created concentric zones measured by time availability based on ten 30-minute time intervals. In our maps, around each of the car assembly plants a buffer consisting of 50% of all suppliers was created. These buffers represent an average time-accessibility between car assembly plants and suppliers. These maps were created using software tools of ArcMap 10.4., which is a part of the program ESRI ArcGIS program and we also used the tool Buffer tool from Geoprocessing tools of ArcMap software.

We find an argument for time-accessibility measure in the case of Poland's automotive industry, where some car manufacturers require some TIER1 suppliers to be located within 20 minutes of the assembly plant or even directly on the assembly plant premises (Gwosdz & Micek, 2010). On the other hand,

JIT does not always mean being in the 'vicinity'. In large countries with well-developed infrastructure, many suppliers are located within one-day time-accessibility interval (Klier & Rubenstein, 2008). Given the fact that Slovakia is a small country with a high concentration of its supply sector in the western part of the country, we decided to use spatial interactions within 30 minutes. That means we focus on supplier interactions at the local and regional levels.

Finally, we used a location quotient to reveal a geographical concentration of suppliers calculated for each of the 30-minute zones delimited around each car assembly plants (10 zones in total). But only five zones (up to 150 minutes) proved to be relevant. The number of suppliers in intervals reaching over 150 minutes from car assembly plants was very low and statistically irrelevant for location quotient calculation. The mathematical equation is the following: (Kopczewska et al., 2017):

$$LQ = \frac{\frac{x_{ij}}{x_i}}{\frac{x_j}{x}}$$

where:

x_{ij} - represents the number of suppliers of the j -th level of supply network (e.g. TIER1) in the i -th time-accessibility zone (e.g. from 0 to 30 minutes),
 x_i - is the number of all suppliers in the i -th time-accessibility zone (from 0 to 30 minutes),

x_j - is the number of suppliers of the j -th level of supply network (e.g. tier-1) of all time zones,
 x - is the total number of suppliers in all time-accessibility zones.

Table 2. Number of TIERS suppliers according to time-distance zones

Volkswagen Slovakia					Group PCA Slovakia				
Time-accessibility [minutes]	TIER1	TIER2	TIER3	Total	Time-accessibility [minutes]	TIER1	TIER2	TIER3	Total
30	22	8	7	37	30	16	12	12	40
60	18	12	11	41	60	44	39	24	107
90	21	30	16	67	90	22	18	19	59
120	17	19	17	53	120	14	11	11	36
150	18	11	12	41	150	2	5	4	11
180	2	5	6	13	180	2	9	1	12
210	2	9	2	13	210	1	4	4	9
240	1	3	3	7	240	3	5	7	15
270	3	6	8	17	270	6	3	2	11
300	5	3	2	10	300	2	5	3	10
300 <	4	5	5	14	300 <	1	0	2	3
Total	113	111	89	313	Total	113	111	89	313
Kia Motors Slovakia					Jaguar Land Rover				
Time-accessibility [minutes]	TIER1	TIER2	TIER3	Total	Time-accessibility [minutes]	TIER1	TIER2	TIER3	Total
30	14	12	10	36	30	15	15	7	37
60	15	14	11	40	60	21	24	25	70
90	14	19	12	45	90	43	30	21	94
120	28	28	27	83	120	17	10	13	40
150	29	26	21	76	150	2	11	5	18
180	5	5	3	13	180	2	7	1	10
210	7	6	2	15	210	1	4	5	10
240	1	1	3	5	240	4	3	5	12
270	0	0	0	0	270	7	6	2	15
300	0	0	0	0	300	1	1	3	5
300 <	0	0	0	0	300 <	0	0	2	2
Total	113	111	89	313	Total	113	111	89	313

Source: Own elaboration according to AIA SR, 2018.

If $LQ = 1$, the spatial concentration of suppliers in a concrete time-accessibility zone equals to the value of the aggregate level. The value above 1 means that particular suppliers in a concrete time-accessibility zone are more geographically concentrated than aggregate level, and vice versa with the value below 1. In Table 2, we present two-dimensional data containing values of the number of suppliers according to time zones and the degree of the supply network.

Results and discussion

The development of the automotive industry in Slovakia began with the arrival of the German VWS plant in 1991 creating a joint venture with BAZ. Despite this large investment, a subsequent growth in the number of automotive industry firms stagnated for two reasons. First, in contrast to the transformation of Škoda, where JIT system with recreation supply network was launched, VW's management decided to build a plant in Slovakia to reduce production costs by transferring the assembly of gearboxes and specific niche-market passenger cars from Germany in order to increase their competitiveness in Western markets. This strategy led to the fact that in the 1990s approximately 85% of the components used in production in VWS were supplied directly from VW component producers in Germany (Pavlínek & Smith, 1998). The second reason had a broader background. Foreign investors perceived the Slovak capital market as too unstable and risky because the corrupt environment of Mečiar's government back in the 1990s had a direct impact on the financial insolvency of privatised industrial enterprises and caused the postponement of privatisation of the banking sector (Williams & Baláž, 1998; Jakubiak et al., 2008).

In 1998, a coalition of right-wing oriented parties won the election and subsequently launched neo-liberal reforms (Rochovská & Smith, 2006). One of the instruments of the state's industrial policy was the Industrial Parks Act of 2001, which committed the government to pay a substantial part of construction

costs for the building of industrial parks. A sufficiently skilled and cheap labour force and the active role of the state's industrial policy led to the arrival of several larger foreign suppliers, which were established in industrial parks in Lozorno, Vrábľe and Kechnec. A number of new foreign subsidiaries in the supply sector began to grow at the turn of the 21st century (Fig 2). As expressed by cumulative distribution, while 50% of all domestic suppliers were founded by 1997, 50% of all foreign subsidiaries came to Slovakia by 2005. The development of a number of suppliers on different levels of the supply network is very similar. While 50% of all TIER1 suppliers were established by 2005, 50% of TIER3 suppliers already existed in 1998. Table 3 confirms that by 2018 we recorded up to 91% of foreign-owned tier-1 suppliers, while less than 4% cover domestic ownership.

Aside from Germany, this asymmetry of the ownership structure is seen in all of Europe (Schmitt & Van Biesebroeck, 2013). Slovakia, however, is the country with the highest index of foreign control (Pavlínek, 2022). The state continued to develop the automotive industry in its investment plans. Its active role in competing with neighbouring countries for FDI resulted in the arrival of PSA (currently Stellantis), KIA and JLR. These competitions were accompanied by generous incentives that reached beyond legal and ethical norms (Kolesár, 2006; Jakubiak et al., 2008, Pavlínek, 2016). Slovakia presents itself as the country with the largest state financial incentives of the automotive industry (Nicolini et al., 2017).

Table 3. Relationship between supplier hierarchy and ownership structure of the firms in the supply sector in Slovakia, 1990-2018

Supplier level / Ownership	Domestic	Foreign	Mixed	Total
TIER1	4	103	6	113
TIER2	19	82	10	111
TIER3	49	37	3	89
Total	72	222	19	313

Source: Own elaboration according to AIA SR, 2018

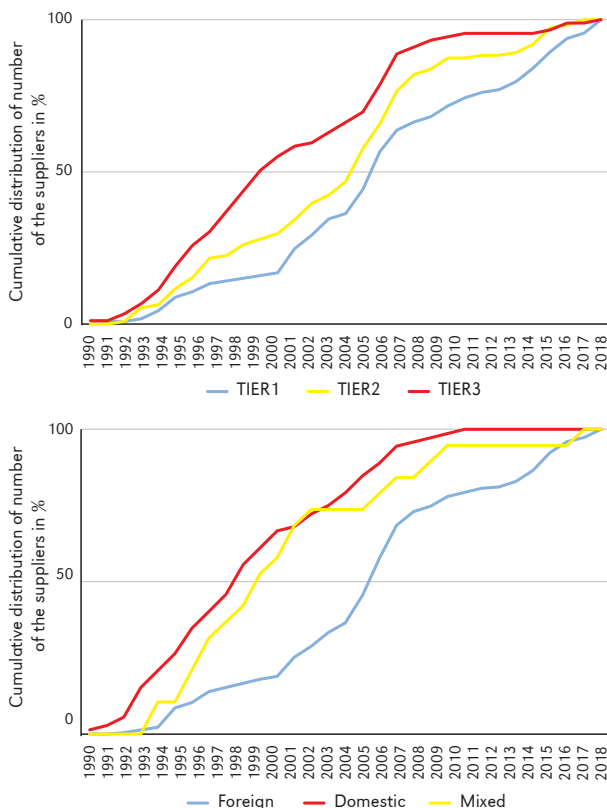


Figure 2. Development of the number of suppliers according to the hierarchy of the supply network (up) and the ownership structure (down) in the years 1990-2018

Source: Own elaboration according to AIA SR, 2018.

Geographical proximity is considered a strong predictor of sourcing success according to econometric models. For example, the location of suppliers 100 km closer to the assembly plant increases the probability of becoming a supplier of parts and components by 2.7%. Locating within a one-day driving distance (700 km) increases the probability of success by 23% (Schmitt & Van Biesebroeck, 2013). We measured the spatial interactions between the location of the assembly plants and the position of supply network firms by time-accessibility. In the attached Figure 3 (A, B, C, D) we present the relative cumulative distribution of firms according to the time values of the accessibility of supply network firms from four carmakers expressed

in 10 30-minute time intervals. Trend lines documenting the generalised level of growth in the number of suppliers depending on the distance from the car assembly plants show various shapes for particular supplier tier levels and for each assembly plant specifically. The results are in line with generally accepted hypotheses. Tier-1 suppliers are located closest to the car assembly plants. This is expressed by the α value, which can be interpreted as the estimated share of suppliers located in the same place as the assembly plant (zero time-accessibility) (Tab. 4). For example, based on the estimated α value of the regression function, more than 40% of tier-1 suppliers are expected to be located in the same location as the Stellantis assembly

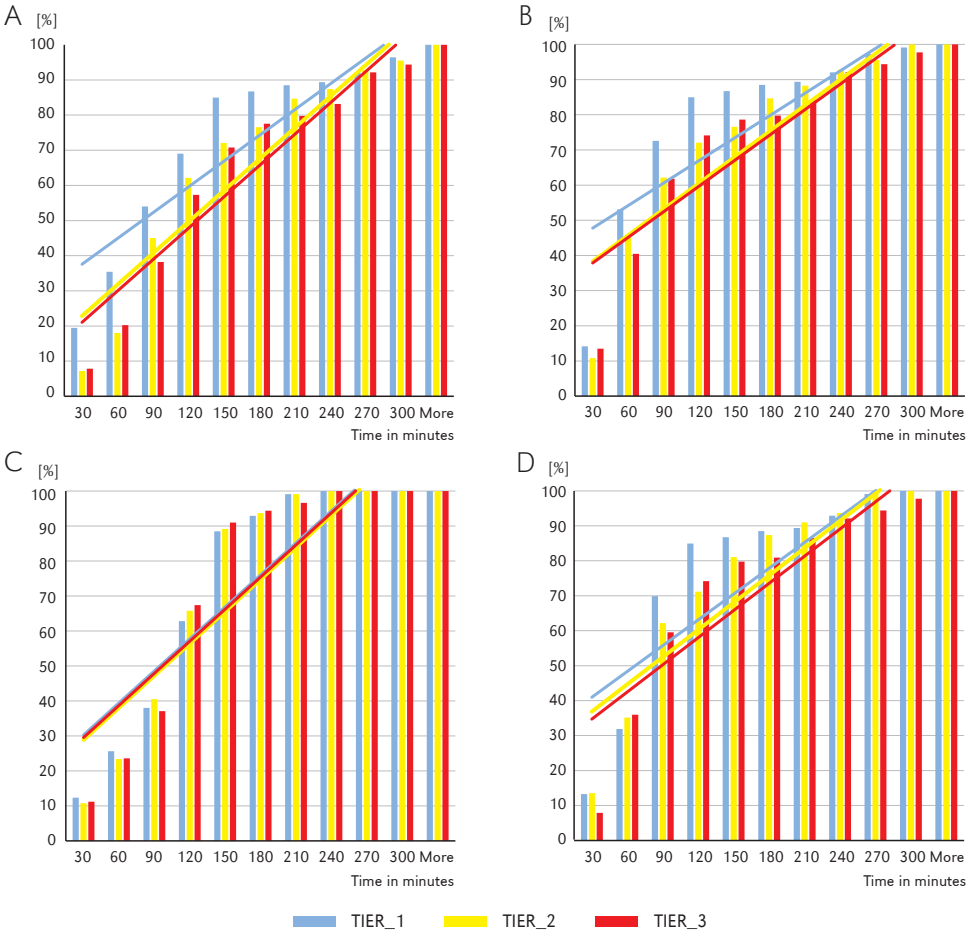


Figure 3. Time-accessibility between assembly plants and firms of supplier sector: (A) – VWS, (B) – Stellantis, (C) – KIA and (D) – JLR (see also Tab. 4)

Source: Own elaboration according to AIA SR, 2018.

Table 4. Values of intercept of linear regression (see also Fig 2).

Assembly plant / α value	TIER1	TIER2	TIER3
VWS	0.3025	0.1294	0.1213
Stellantis	0.4138	0.3088	0.3056
KIA	0.1961	0.1974	0.1963
JLR	0.3356	0.2906	0.2691

Source: Own elaboration according to AIA SR, 2018.

plant. The lowest α values are achieved by TIER3 suppliers. In the case of VWS, the estimated α value indicates that only 12% of all TIER3 suppliers should be located at the site of the VWS assembly plant.

Figure 4 (A, B, C, D) help us to visualise the spatial distribution of the supply network. It specifically shows that 50% of all TIER1 suppliers are located up to 85 minutes from VWS, 56 minutes from Stellantis, 104 minutes from KIA and 70 minutes from JLR. The spatial pattern of tier-3 suppliers from assembly plants is quite different, because 50% of all tier-3

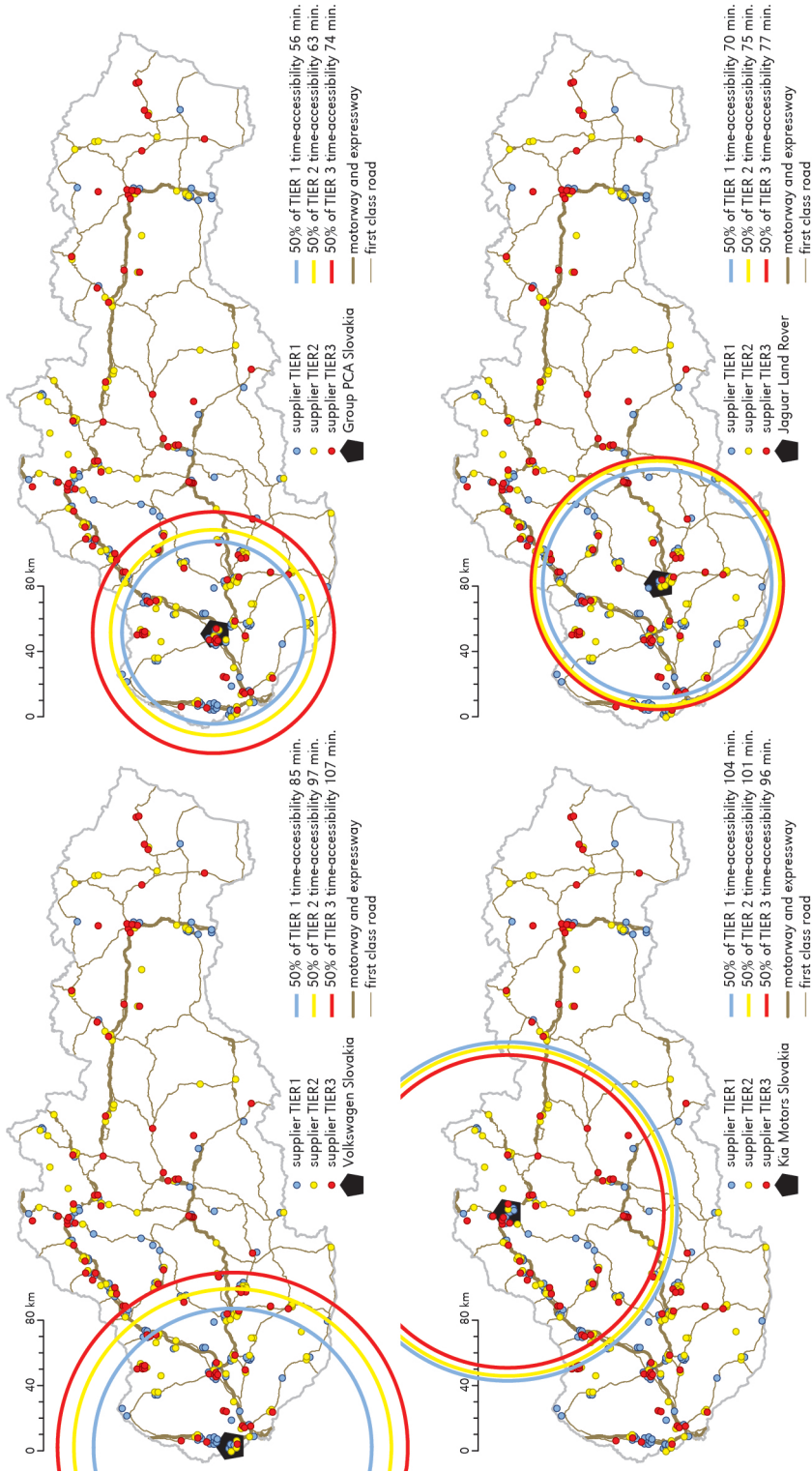


Figure 4. Spatial distribution of the supplier network for a particular assembly plant (A – Jaguar Land Rover, B – Kia Motors Slovakia, C – Group PCA Slovakia, D – Volkswagen Slovakia)

Source: Own elaboration according to AIA SR, 2018.

suppliers are located up to 107 minutes from VWS, 74 minutes from Stellantis, 96 minutes from KIA and 74 minutes from JLR. The differences in the location of suppliers according to their position in the supply network to individual assembly plants are of interest. In the case of VWS, which established itself in Slovakia in 1991, and Stellantis, which is located in a 60-minutes-drive distance from VWS, the difference in time accessibility between the location of tier-1 and tier-3 suppliers in 2018 was 22 minutes or 18 minutes, respectively. In the case of KIA with cross-border suppliers' linkage and of JLR, which established itself in Slovakia in 2018, these spatial regularities are disappearing (see Fig. 3). The difference in time accessibility between the location of tier-1 and tier-3 suppliers is reduced to 8 and 7 minutes, respectively. In the case of KIA, the time-accessibility of 50% of all tier-3 suppliers is 8 minutes less compared to 50% of all tier-1 suppliers. One of the reasons for the lower representation of tier-1 suppliers lies in the fact that the KIA assembly plant is a part of the Hyundai automobile group, which has an assembly plant

located in Nošovice in Czechia, 120 minutes away from Žilina, with a part of the supply network for KIA. The radius goes beyond the territorial border of Slovakia and expands to historical Upper Silesian Industrial District and the Bielsko-Biała area (Gwosdz & Micek, 2010; Domański & Gwosdz, 2018) and the Moravia-Silesia automotive cluster (Pavlínek & Žižalová, 2016). In the case of the JLR investment, which came to Slovakia in 2018, we claim that it was located within the built environment with an existing network of suppliers.

Finally, we evaluated the geographical concentration of suppliers based on their position in the supply network according to time-accessibility from car assembly plants (computed as an average of all four car assembly plants' accessibility values). As mentioned above, the values obtained for time distance intervals higher than 150 minutes are irrelevant for interpretation because they involve a small number of suppliers. Figure 5 shows that tier-1 suppliers are the most concentrated ones within 30 minutes. They maintain a relatively high degree

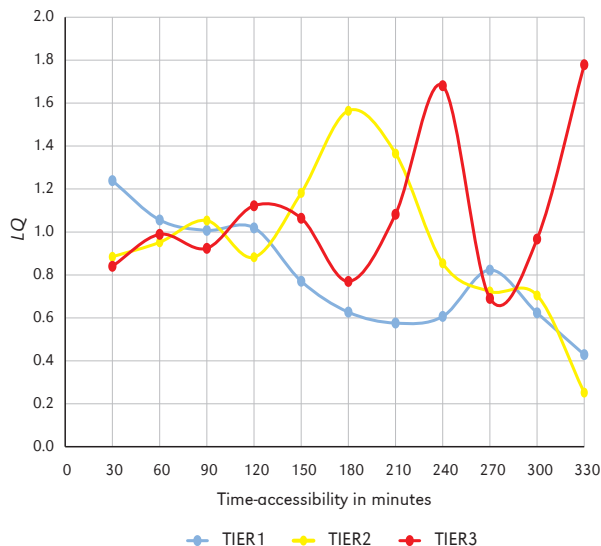


Figure 5. Geographical concentration of supply sector according to average time-accessibility from car assembly plants

Source: Own elaboration according to AIA SR, 2018.

of geographical concentration up to 120 minutes. The highest geographical concentration of tier-2 suppliers is seen between 60- to 90-minutes accessibility intervals around car assembly plants. In contrast, the value of geographical concentration of tier-3 is the lowest, but in time-accessibility from 90 to 120 minutes it reaches higher values than the supply levels tier-1 and tier-2.

Our research focus on local and regional level confirms localisation strategies of TIER1 suppliers, which benefits from localisation economies in several ways: co-localised suppliers clusters (Reichhart & Holweg, 2008), suppliers park (Larsson, 2002), linkages and spillovers (Pavlínek & Žířalová, 2016). In contrast, TIER3 suppliers benefit from lower-cost peripheral locations in the less developed regions with below-average wages (Ženka et al., 2017). These findings should be empirically verified in future investigation.

Conclusion

We analysed the spatial patterns of the automotive supply network in Slovakia. Our theoretical framework includes two theoretical concepts. The integrated periphery, which Slovakia is a part of, represents the dynamic low-cost industrial space where the final phase of car production is temporarily moved, followed by a network of suppliers (Pavlínek, 2018). Using the concepts of spatio-temporal fixes (Pavlínek, 2018) and the theory of the smiling curve (Mudambi, 2008), we explain why automobile assembly activity has the lowest share value added of the total value of production and is carried out in low-cost regions. The second concept is associated with nested structure with focus on the regionally integrated local clusters (Sturgeon et al., 2008). This spatial level is based on modular production, which hierarchized the supply sector based on the degree of production complexity of modules and systems and quality and speed of delivery and enabled global mega suppliers, so-called tier-1 suppliers, to emerge (sometimes labelled as TIER 0.5, Frigant & Layan, 2009).

When identifying the spatial patterns of time-accessibility between tier-1, tier-2 and tier-3 suppliers and assembly plants, the hypothesis on the geographical proximity of tier-1 suppliers was only partially confirmed. Tier-1 suppliers are located close to assembly plants to satisfy JIT and JIS requirements of car the assembly plants. On average, tier-1 suppliers are located within 80-minutes, tier-2 within 84 minutes and tier-3 within 89 minutes accessibility interval. Moreover, our results indicate the differences between the time-accessibility of suppliers in different tiers between VWS, which established itself in Slovakia in the 1990s, and JLR, which came to Slovakia in 2018. We find that, 50% of all suppliers were established by 2004. Thus, JLR arrived into a well-built environment with an existing network of suppliers.

Finally, we evaluated the geographical concentration of suppliers' network around car assembly plants. Tier-1 suppliers reach the highest values of geographical concentration in the time zone within 30 minutes. As the average distance from assembly plants increases, their geographical concentration decreases. Mathematically expressed, with every 10 km away from the assembly plants the value of the geographical concentration tier-1 suppliers decreases by 10% (measured by the LQ). Tier-2 suppliers reach the highest values of geographical concentration between time-accessibility of 60 to 90 minutes and tier-3 suppliers from 90 to 120 minutes.

In the end, we propose some implications for regional policy. Firms are constantly developing strategies to take advantage of the comparative advantages of localities and regions. The localization strategies of suppliers are conditioned by the geographical (macro) location and settlement system. Slovakia's development opportunities are given by the east-west direction and the significant eccentric location of the capital in the western part of the country (Halás et al., 2018). The area with the largest supply networks can be found in the central part of Považie region on the motorway corridor that stretches from Žilina to Bratislava (Jacobs, 2017). The

arrival of the fourth carmaker JLR in Nitra is important for other suppliers, development of local SMEs, influx of new labour force but it may also cause high intensity of road traffic (Filčák et al., 2021). Today it is much more efficient to support domestic suppliers in the western part of Slovakia, because domestic firms are having problems achieving technological and knowledge linkages with and spillovers of foreign firms (Šipikal & Buček, 2013; Pavlínek, 2018). In contrast, the supply network in central and eastern Slovakia is scattered, except for the Košice and Prešov regions. A frequent explanation of less developed regions lies in insufficiently developed transport infrastructure towards the east of Slovakia (Baláž et al., 2018). Even generous government incentives are not a sufficient guarantee to attract foreign investors to eastern Slovakia, unless the transport connection with western Slovakia is completed.

As Pavlínek (2016: 588) claims, “state industrial policies in Slovakia have been subordinated to the needs of foreign capital (...), large investment incentives and low corporate taxes undermined the ability of the state to finance adequately domestic research, education and the support of domestic firms.” Slovakia is doomed to remain an integrated periphery of the automotive industry, because of a low-cost labour, high degree of foreign control and low innovation capacities.

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Unless otherwise stated, the sources of tables and figures are the authors', on the basis of their own research.

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