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VIZE BUDOUCÍHO VÝVOJE OSOBNÍ A NÁKLADNÍ DOPRAVY V ČESKÉ REPUBLICE SE ZVLÁŠTNÍM ZŘETELEM NA ÚZEMÍ JIHOMORAVSKÉHO KRAJE

D.T2.4.2 – Scenarios of development of freight transport crossing and targeting the South Moravian Region

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INTRODUCTION

The aim of the present study is to formulate visions of the future development and arrangement of passenger and freight transport, both in a general form valid for the Czech Republic and in a more specific form concerning the territory of the city of Brno and the South Moravian Region (i.e. specific manifestations of the vision in this territory and implications of the vision for the territory). The time horizon towards which the formulation of the visions for passenger and freight transport is directed is the next decades of the first half of the 21st century with the target date in 2050.

The internal structure of the study is subordinated to the above mentioned aim. The first parts of the study are therefore devoted to the current state of passenger and freight transport in the Czech Republic. In the context of the formulation of long-term transport visions, the current situation can be considered to be the development currently observed. Within this framework, emphasis is placed on the period of the last twenty years, since for this period numerous data sets are already available from transport yearbooks, statistics from the Ministry of Transport of the Czech Republic, the Czech Statistical Office, Eurostat or other statistical sources. Moreover, in the case of the Czech Republic, this period includes a number of key events of a (geo)-political or technological-economic nature that have determined the current transport situation. The Czech Republic also joined the European Union during this period, thus completing the post-socialist transformation. In the long term, this event has had a quite radical impact on international transport in all sectors, some of which reacted immediately, others with some delay. The accession of the Czech Republic to the EU was gradually followed by other important events, such as the application of the common transport policy, the form of which, of course, to a large extent influenced national approaches to regulation or deregulation of transport market conditions or the promotion of more environmentally friendly modes of transport.

The passages that characterise the current state of passenger and freight transport on the basis of available statistical data are complemented in the next part of the study by an analysis of the key development trends concerning individual segments of the transport market, or individual modes of transport currently involved in modal split/work sharing. These passages have been prepared on the basis of extensive excerpts from specialist literature, mainly of geographical, economic or transport engineering provenance, or on the basis of other studies prepared by respected organisations and institutions (European Union, UIC - International Union of Railways, Ministry of Transport of the Czech Republic, etc.). Attention is paid in particular to those tendencies and trends that have the potential to influence the development of the passenger and freight transport market in the next decades of the first half of the 21st century.

The main conclusions resulting from the analysis of the current state of passenger and freight transport, as well as from the characterisation of current development trends in individual segments of the transport market, are briefly presented in the study in the form of two clear SWOT analyses (one describing the situation in passenger transport, the other in freight transport).

These analytical and overview chapters are followed by a key passage containing a formulation of visions for the future development and arrangement of passenger and freight transport in the Czech Republic with a more detailed specification of the impacts on Brno and the South Moravian Region. The visions are elaborated with a view to 2050. Due to the distance of the time horizon of the study, the form of extrapolation of current trends on the transport market was not chosen, but the form of several alternative scenarios. Although it is clear that the future development of transport will be influenced by a number of sub-factors and realities, which, moreover, will strongly influence each other, we have

attempted to identify several key groups or axes of determination within them. These are (i) the degree of regulation or deregulation of the transport system, (ii) the extent of expected technological innovation, and (iii) the existence of a broad group of other issues with the potential to modify ongoing developments in a different direction. These groups of factors/determinant axes have subsequently also become the basis for the definition of four sub-scenarios of future transport development:

- The *business-as-usual scenario* is based on the continuation of existing trends in the transport market, which are not significantly modified either by regulatory interventions or by the advent of major technological innovations;

- The *futuristic transport system development scenario* is based on the assumption of the successful introduction of major technological innovations that will transform the existing transport system without the need for harsh regulatory measures;

- the *transport market regulation scenario* assumes that in the next decades there will be a massive impact on the transport system as a result of the introduction of regulations of different nature, which will also concern different scales of the transport market (regulation in accordance with the current transport policies of the EU, the Czech Republic or the city of Brno);

- The *realistic transport system development scenario* represents the intersection of the key trends presented in all previous scenarios.

At this point, we think it is worth emphasising that the author's team is aware, given the relatively distant time horizon of the study, 2050, that the visions presented for the future development and organisation of passenger and freight transport are largely speculative. In fact, a number of events of various kinds may take place over the next 30 years which may significantly affect the currently valid assumptions and assumptions underlying the formulation of the visions. These events may be economic or political changes, but they may also be unexpected technological breakthroughs or even a series of minor events that, in combination, may divert the future development of transport and mobility behaviour in a completely different, alternative direction. Readers and users of this study will therefore be grateful if they keep in mind the idea that the future, even the one presented here in the transport scenarios, is always only hypothetical.

1. PERSONAL TRANSPORT

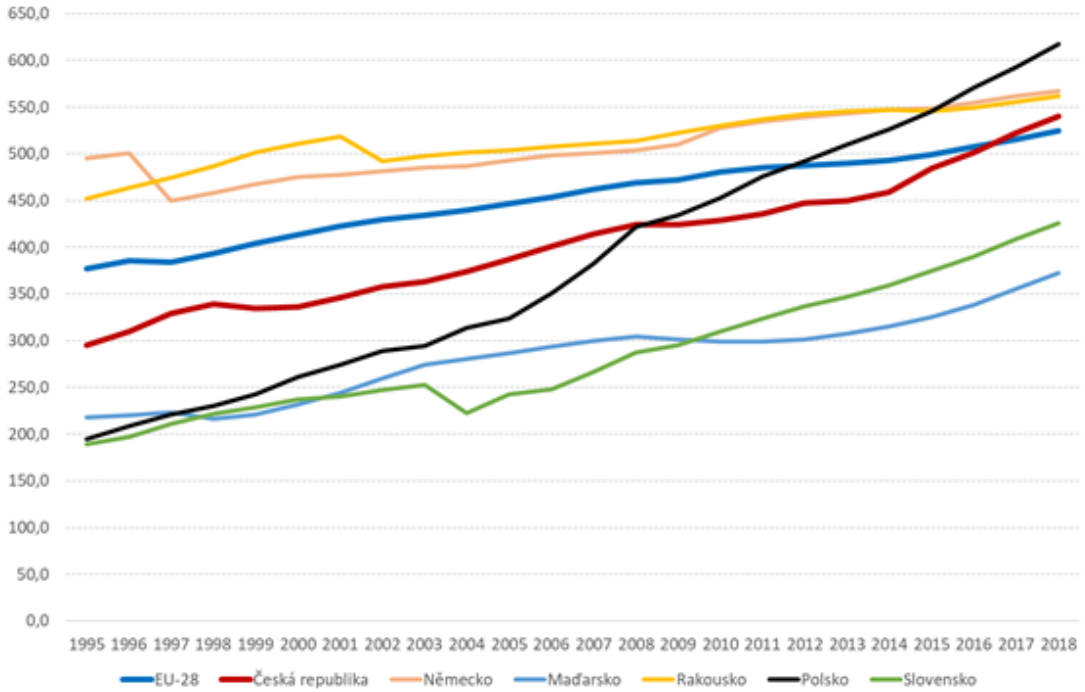
2.1 THE STATE OF PASSENGER TRANSPORT BASED ON THE ANALYSIS OF STATISTICAL DATA

2.1.1 International comparison

It is appropriate to start the characterisation of the current state of passenger transport in the Czech Republic by comparing the overall arrangement of the local transport market with the situation in the European Union and also in selected neighbouring countries (see Figures 1, 2 and 3). In this comparison, the Czech Republic shows some positive tendencies, the most significant of which is the relatively higher share of public transport in transport performance - in the Czech Republic, trains, buses and urban transport together account for more than 30% of the transport market made up of land transport modes throughout the period under review, whereas in the EU-28, public transport has been stable at only 18-19%. The positive difference in favour of the Czech Republic is, in our view, due both to the relatively high quality of services provided by public transport and to the continuing tradition of using public transport routinely in everyday life. Fortunately, this habit has survived the post-socialist transformation of the transport market. Mass transport is used quite intensively in our country, despite the fact that the rate of motorisation has been increasing quite rapidly from the early 1990s to the present day. Its current value, 540 passenger cars per 1,000 inhabitants (as of 2018), is already fully comparable with Western European countries.

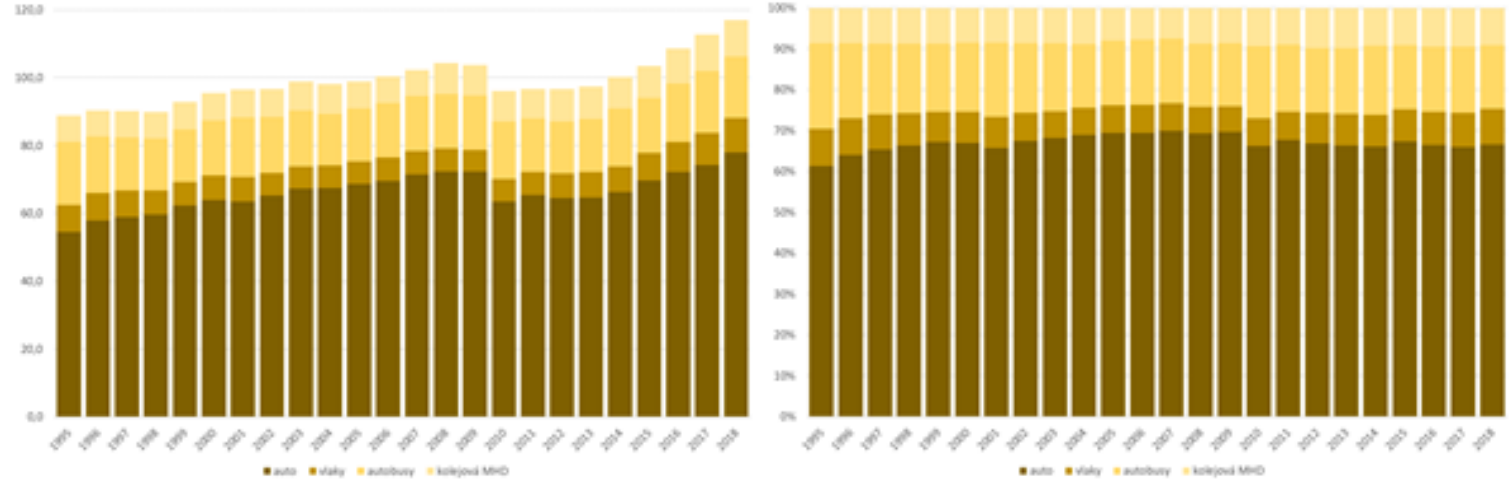
The described state of modal split/division of transport work on the passenger transport market in the Czech Republic represents a good starting point for the planned changes in the transport market arrangement consisting in the reduction of the importance of individual car transport and the growth of the importance of public transport. The Czech Republic is well placed for such a change in international comparison.

Fig. 1: Automobiles in the Czech Republic and neighbouring countries (number of passenger cars per 1000 inhabitants), 1995-2018



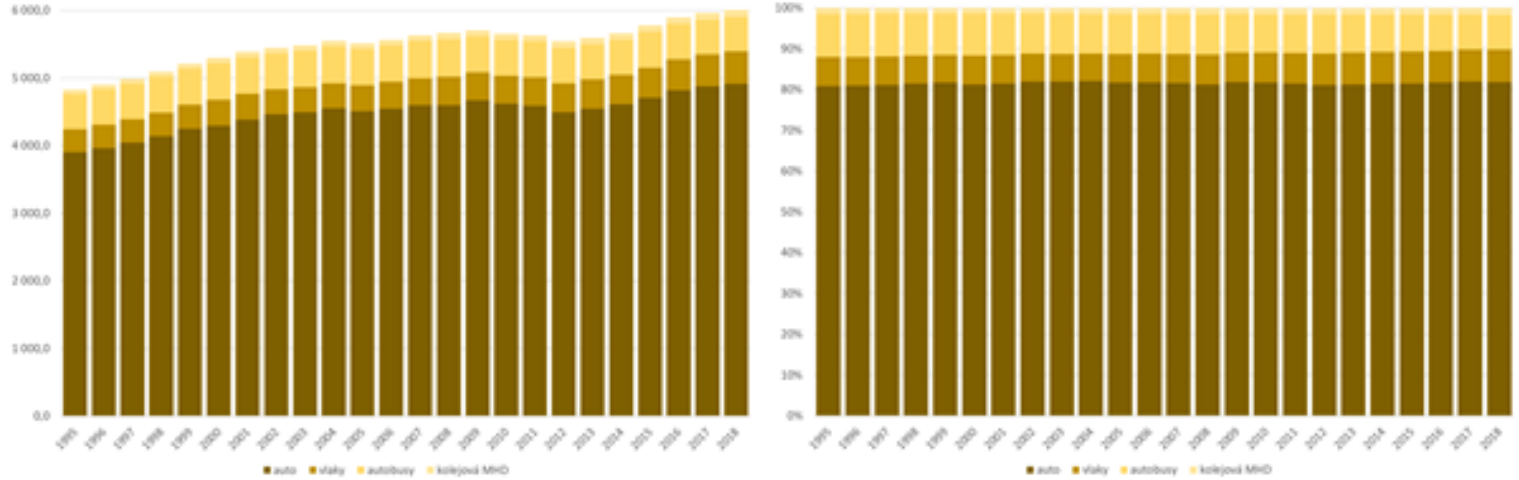
Source: European Union (2020)

Fig. 2: Modal split in passenger land transport in the Czech Republic: in billion oskm (left), in % (right), 1995-2018



Source: European Union (2020)

Fig. 3: Modal split in passenger land transport in the EU-28: in billion oskm (left), % (right), 1995-2018

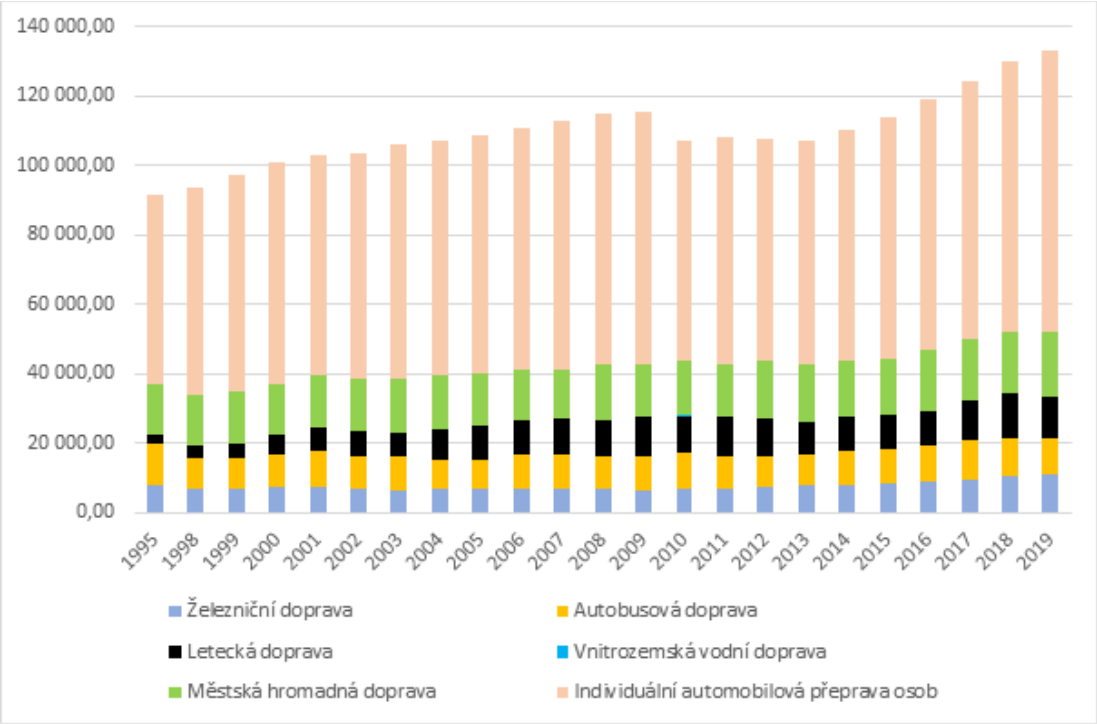


Source: European Union (2020)

2.1.2Personal transport in the Czech Republic - key indicators

Figure 4 presents the development of transport performance of individual passenger transport modes in the Czech Republic. The long-term growth trend of this indicator was interrupted by the financial crisis starting in 2009. This crisis hit the passenger transport sector with a roughly one-year delay in 2010 and its effects lasted until 2014.

Fig. 4: Intermodal development of transport performance (mil oskm)



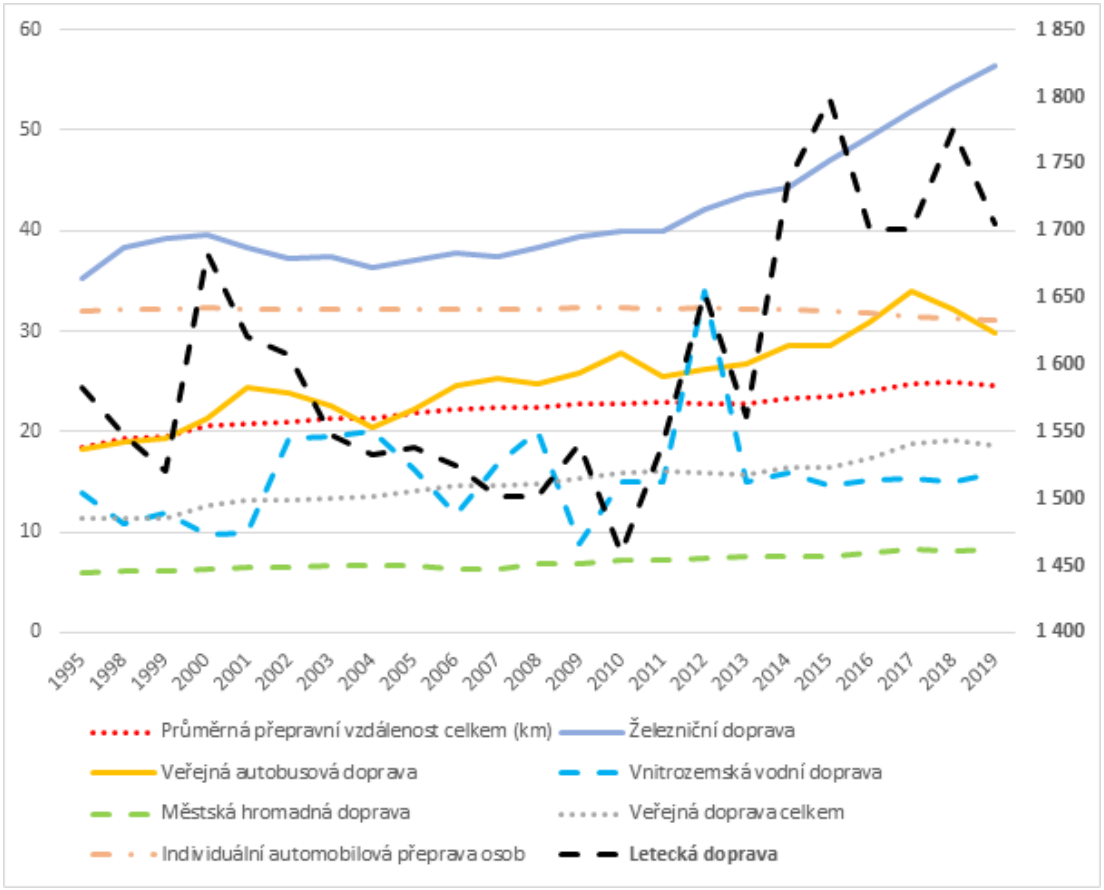
Source: 1998 to 2019 Transport Yearbooks

An interesting variable in passenger transport is the average transport distances; their development, as recorded in Figure 5, reflects some of the societal phenomena of recent decades. The overall average transport distance for all modes has increased from 18 to 25 km over the period, i.e. on average, the average transport distance increases by 1 km in about 3.5 years. However, it is necessary to look in more detail at the individual modes. In terms of transport distance, the most important individual car mode has stagnated at 32 km throughout the period under review, even falling slightly to 31 km in recent years. This relatively low average value probably reflects the now key importance of the private car in providing regular commuting to work and other activities at the spatial scale of town centres and their immediate hinterland. A relatively significant increase in average travel distance was recorded for bus transport, from 18 to 30 km, i.e. 67%. In this development, the influence of Student Agency cannot be overlooked, which in 2004, started intensive operations on domestic long-distance lines, first from Prague to Brno and then to Plzeň, and then in the following years added more lines to many more and less important cities in the Czech Republic. The average transport distance also increased substantially on rail, from the initial 35 km to the final 54 km, i.e. by 60%. A clear breakthrough in rail transport came in 2010, the main reason was obviously the process of liberalisation of the railway market and especially the beginning of open access on the Czech railway in 2011, when RegioJet started to operate the Prague - Ostrava - Čadca - Žilina line, followed by Leo Express, which joined in 2012 with the Prague - Ostrava - Bohumín line, with Czech Railways operating

the lines on a permanent basis. Later, RegioJet significantly expanded its offer to include services on the Prague - Brno route and from there on to Bratislava (2016) or Vienna (2017).

In addition to the developments in the long-distance market segment, the above-described increases in average transport distances for individual modes of public transport must be put into the context of the ongoing process of metropolization of the Czech Republic (Hampl, Marada, 2016; Šauer, Pařil, Viturka, 2019), including the accompanying suburbanization phenomena. These processes increase the pressure on the coverage of larger areas around metropolitan or agglomeration centres by public transport and its further integration with regional/suburban integrated transport systems implemented by bus and rail transport. Thus, the process of metropolitanisation of the Czech Republic contributes to the increase in the requirements for the growth of average transport distances in public transport in the long term.

Fig. 5: Average transport distance (km)

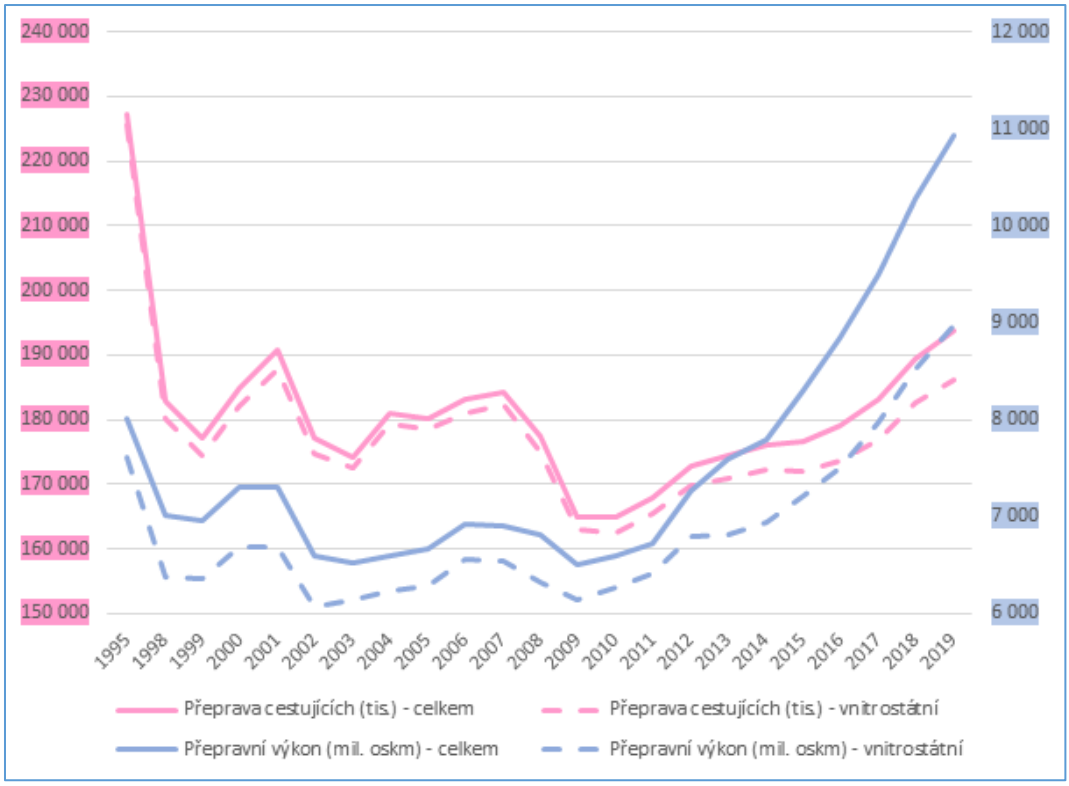


Source: 1998 to 2019 Transport Yearbooks

Passenger rail transport

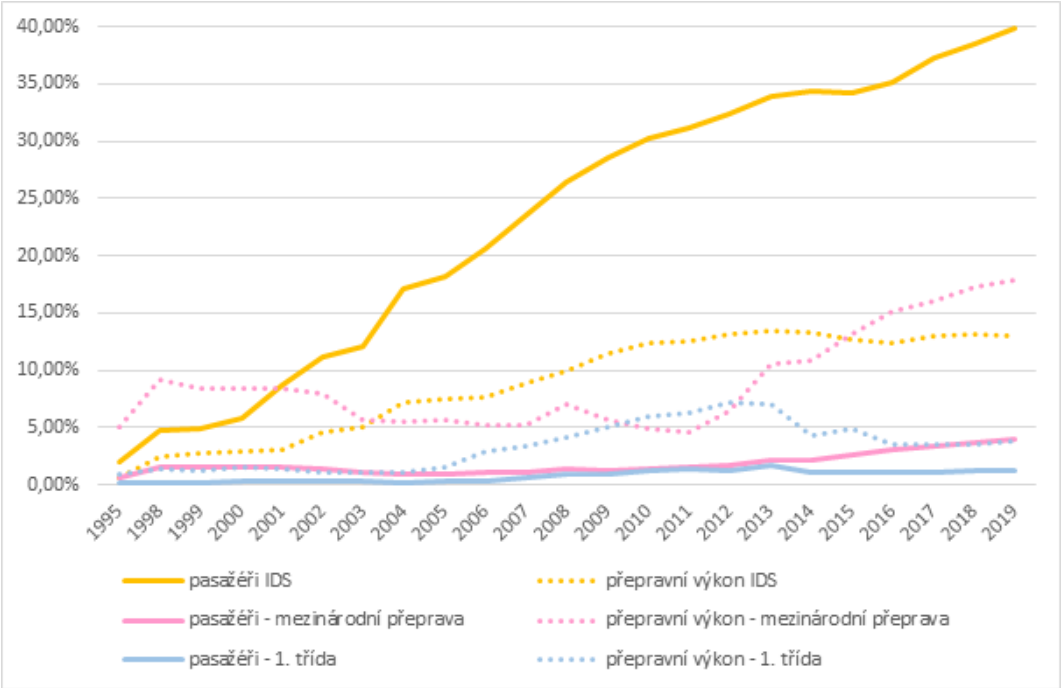
The overall development of the number of passengers transported as well as the transport performance of rail transport, taking into account total and domestic transport, is shown in Figure 6. After 2010, the Czech railway is clearly opening the scissors between total and domestic transport performance, with relatively simultaneous development of total and domestic passenger transport. This is a consequence of the faster growth in the length of journeys abroad compared to those within the country.

Fig. 6: Passenger and transport performance by rail (including domestic transport)



Source: 1998 to 2019 Transport Yearbooks

Fig. 7: Status of ITS, international transport and 1st class passengers on rail



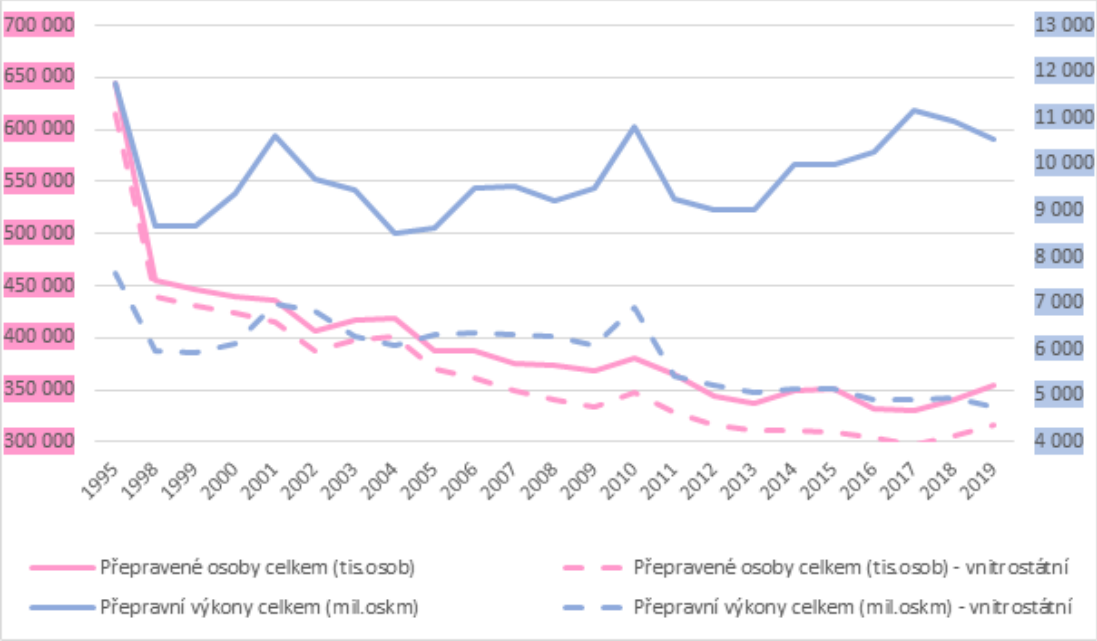
Source: 1998 to 2019 Transport Yearbooks

Figure 7 reflects this development from a different point of view.The share of international transport in the total number of passengers on Czech railways has increased from 0.66% in 1995 to 3.97% in 2019 (sixfold). In terms of transport performance, the analogous values in the same years are 5.03% and 17.92% (a three-and-a-half-fold increase in significance within the railway). Interesting is also the seemingly different trend in the rapid growth in the number of passengers travelling by train within the IDS, which, however, does not lead to such a rapid growth in transport performance - such a development is a consequence of the shorter distances typical for this part of the passenger rail market.

Bus transport

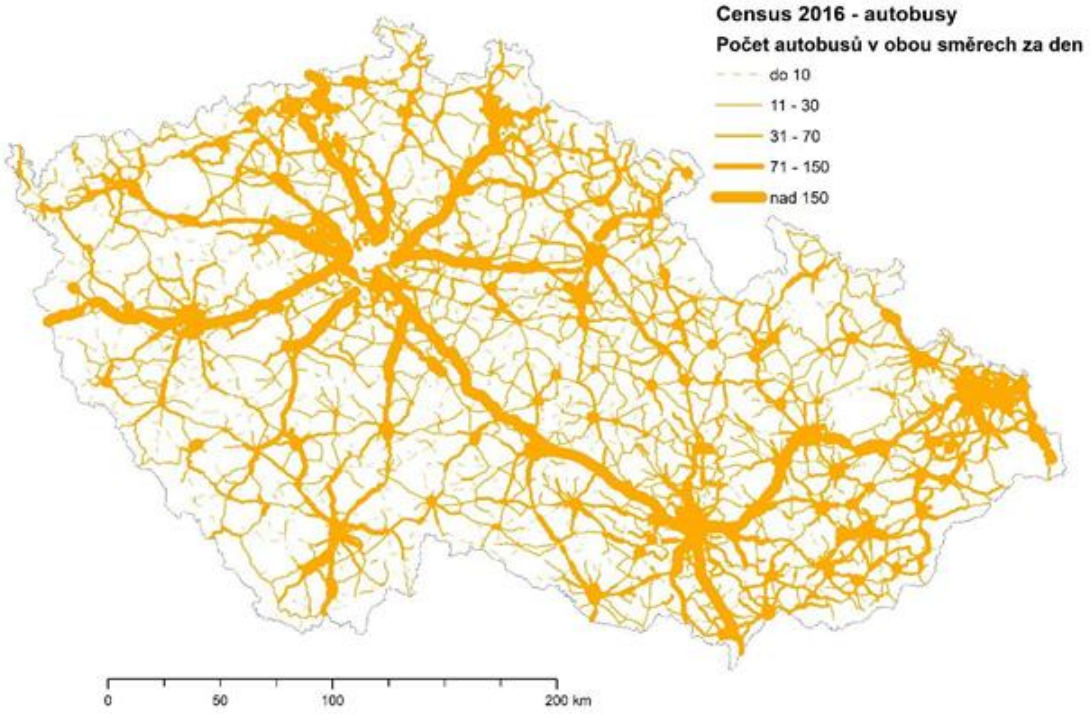
In bus transport, as well as on rail, there is a relative increase in the importance of international transport (see Figure 8, the opening of the scissors between total and domestic transport performance). The intensity of bus transport within the road network of the Czech Republic is approximated by Fig. It can be seen from the figure that the main bus corridor across the Czech Republic runs in the direction from Bratislava, past Breclav towards Brno (D2), then towards Prague (D1), and then towards Pilsen and Nuremberg (D5). From this corridor there are important branch lines from Brno to Olomouc (D1/46), and also from Prague to Liberec (D10), Ústí nad Labem (D8), Příbram (D4) and Kladno (along D6 and D7). Interestingly, the D1 motorway between Olomouc and Ostrava does not have such a significant bus stream, which also precludes the existence of a significant bus stream between Brno and Ostrava. The connection between Ostrava and Prague is, quite logically for geographical and infrastructural reasons, mainly served by rail. Nor is the strong bus stream in the direction from Prague to Liberec and Jablonec nad Nisou, where, on the contrary, there is no reasonable rail connection, uninteresting. The map also clearly shows all other centres of population such as regional and district towns or administrative municipalities of the ORP, which function as clearly developed centres of regional bus transport.

Fig. 8: Development of passengers and bus performance (including domestic transport)



Source: 1998 to 2019 Transport Yearbooks

Fig. 9: Bus operation on roads in the Czech Republic according to the 2016 Census

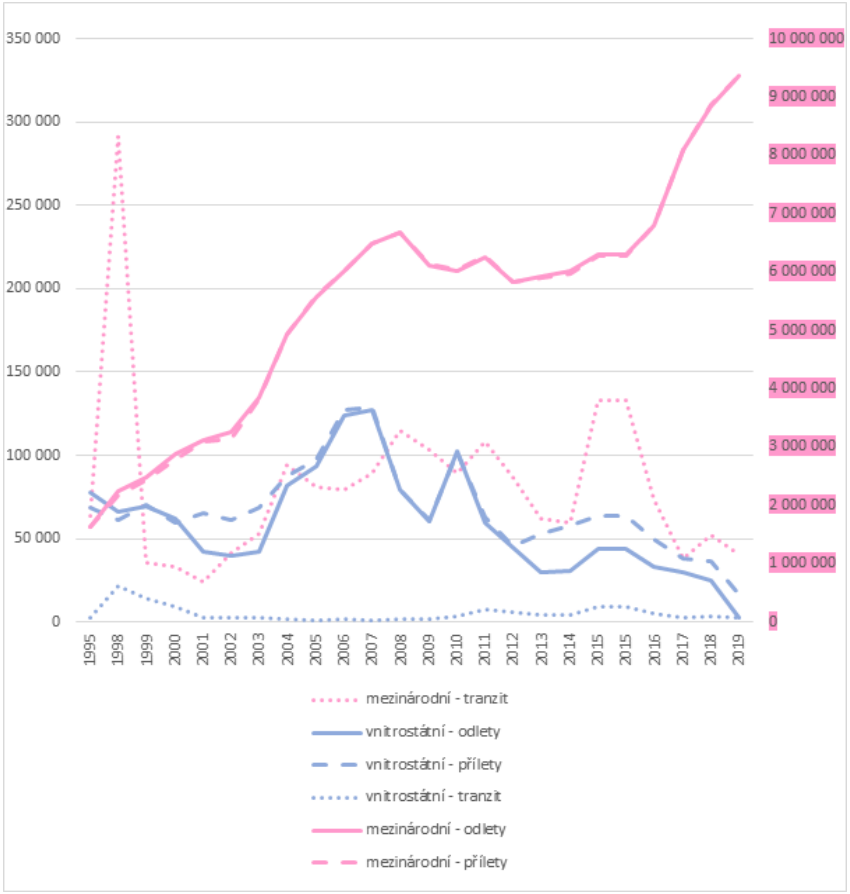


Source: 2016 Transport Census

Air transport

The following Figure 10 shows the utilisation of airports in the Czech Republic in terms of domestic and international departures, arrivals and direct transits. This figure documents the gradually declining to disappearing role of domestic air transport in terms of all three variables over the whole period. Conversely, the role of international air transport in terms of arrivals and departures increases significantly throughout the period, but the role of transit decreases (a consequence of the gradual decline of CSA and the importance of its hub at Prague Airport).

Fig. 10: Development of passengers and transport performance in commercial air transport in the Czech Republic (in thousands of passengers and millions of passenger-km)

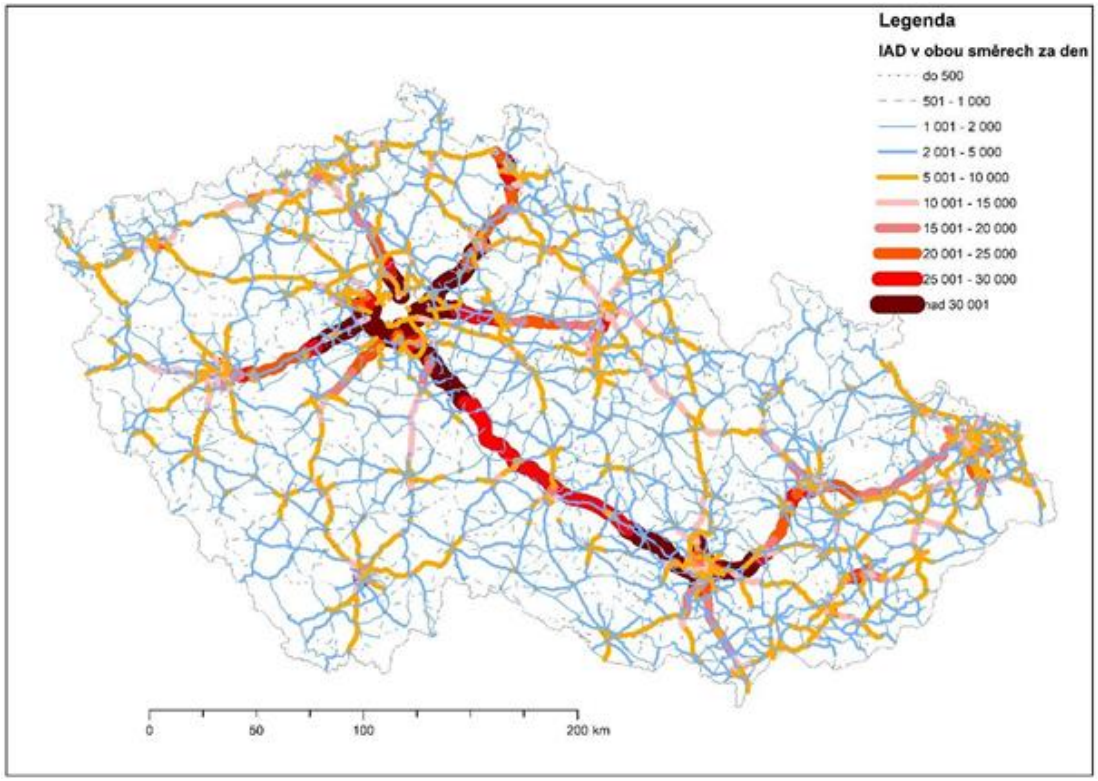


Source: 2000 to 2019 Transport Yearbooks

Individual car transport

This chapter focuses on the most heavily used component of passenger transport, namely individual car transport. Figure 11 shows the intensity of passenger car traffic on roads in the Czech Republic according to the 2016 Transport Census. The figure shows the key traffic corridors for individual car traffic in the Czech Republic. The most important line is the link between Prague and Brno, which continues from there to Ostrava. The aforementioned traffic route on the other side from Prague divides into two directions of comparable traffic importance - one to Pilsen and the other to Liberec. Other important corridors of car traffic are the connections between Prague and Hradec Králové, Ústí nad Labem and Příbram.

Fig. 11: Passenger car and van traffic on roads in the Czech Republic according to the 2016 Census

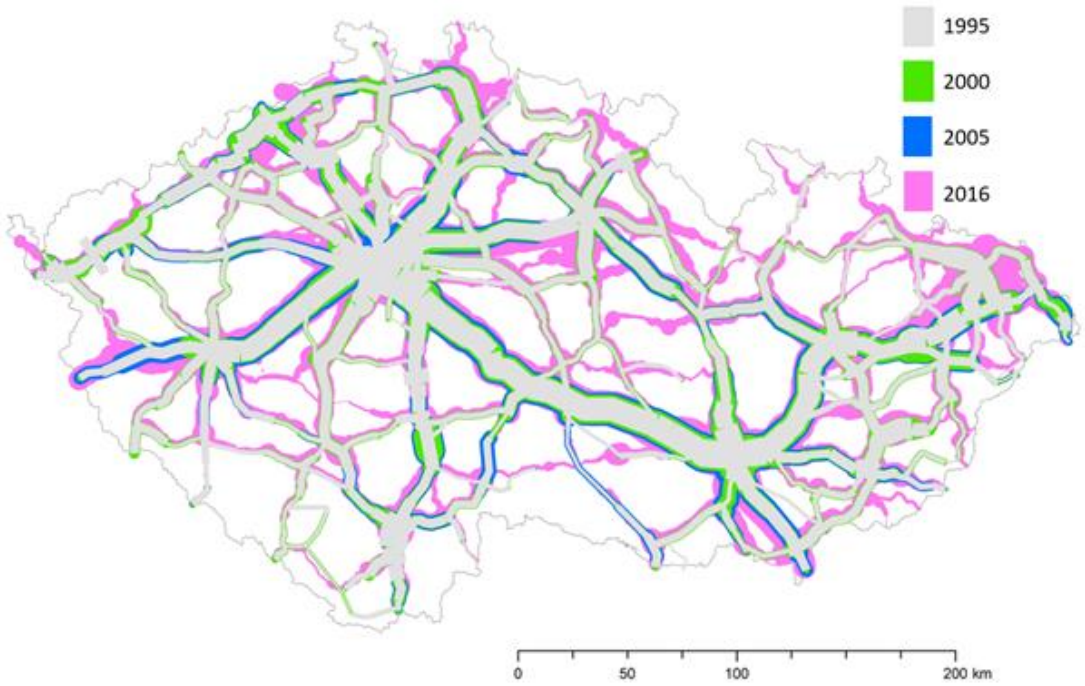


Source: 2016 Transport Census

Figure 12 shows the long-term evolution of the total cumulative traffic volume on the main road routes in the Czech Republic, specifically between the 1995, 2000, 2005 and 2016 traffic censuses (2010 is omitted due to data unavailability). Traffic volume in the Czech Republic has been gradually increasing over the last 25 years, but at the same time it is clear that there is a certain "spillover" of traffic flows. This occurs mainly in places where there has been a qualitative change in the infrastructure, especially the completion of a new motorway section (see in particular the D1 sections around Ostrava, the D1 section towards Hulín, the acceleration of the road between Hradec Králové and Pardubice, the D5 section from Plzeň towards Germany, the D11 section from Prague to Hradec Králové, the D8 motorway in the direction from Prague to Ústí nad Labem, etc.).

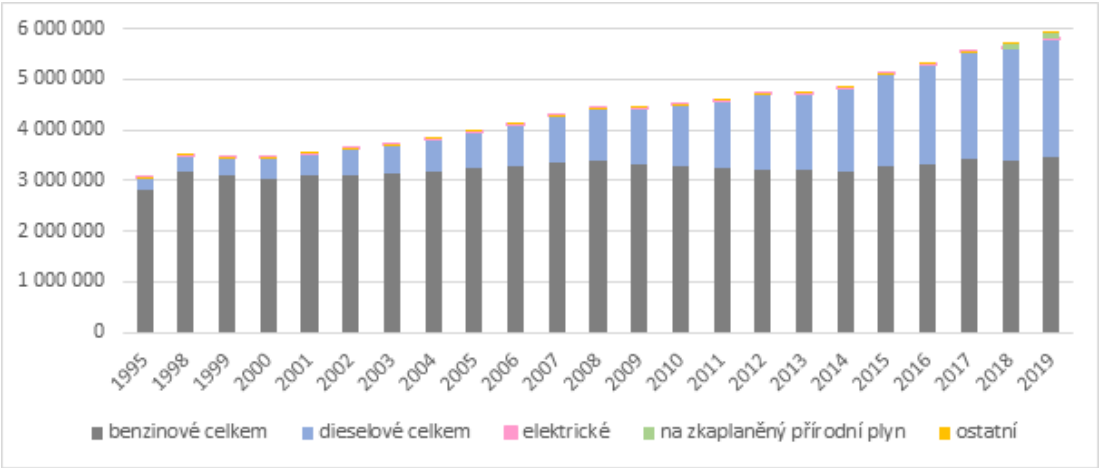
Compared to 1995, traffic volumes started to increase noticeably in 2000 also in the vicinity of major metropolitan or agglomeration centres and their catchment areas, and then in 2005 the increase in traffic volumes is also visible at greater distances from them. This effect thus confirms one of the accompanying phenomena of the suburbanisation process - the rise in the intensity of commuting by car. The process of suburbanisation in the Czech Republic started around the mid-1990s, which corresponds well with the period of a clear increase in traffic intensity in the hinterland of strong population centres.

Fig. 12: Traffic volume development on motorways and class I roads in 1995, 2000, 2005 and 2016 according to individual traffic censuses



Source: 1995, 2000, 2005, 2016 Transport Census

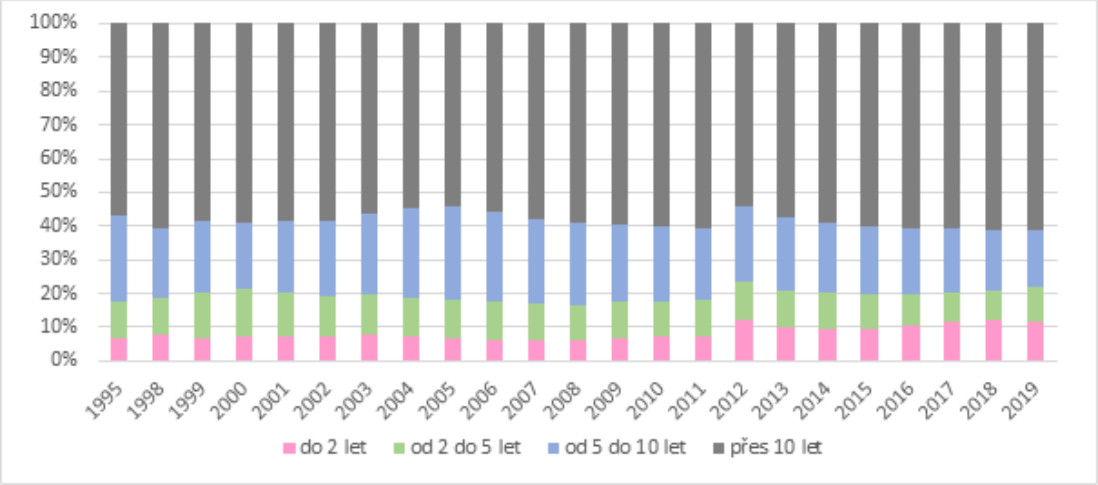
Fig. 13: Number of passenger cars by type of powertrain in the Czech Republic



Source: 2000 to 2019 Transport Yearbooks

The total number of passenger cars registered in the Czech Republic almost doubled between 1995 and 2019, from around 3 million to just under 6 million vehicles (see Figure 13). Within the fleet of registered vehicles, petrol vehicles predominate, but the continuous increase in the representation of diesel cars is also very clear (their share now reaches almost two-fifths of the fleet). Figure 14 shows the structure of registered cars by age, distinguishing several categories. The above figure shows at a glance that there has been no significant rejuvenation of the car fleet over the whole period under review, with only a slight improvement in the strengthening of the category of the youngest vehicles (up to 2 years old) at the expense of vehicles in the categories up to 5 and up to 10 years old.

Fig. 14: Representation of passenger cars by age in the Czech Republic



Source: 2000 to 2019 Transport Yearbooks

2.1.3Personal transport in the South Moravian Region - the same or different trends compared to the Czech Republic

Passenger transport in the South Moravian Region in the monitored time horizon shows similar characteristics as transport in the whole Czech Republic, however, it is appropriate to focus in this section on a more detailed analysis of trends in public transport provided in the territory of the Region. In terms of structure, taking into account the number of passengers carried, the most significant share is held by the trams of the Brno City Transport Company (DPMB), which carry a gradually decreasing share starting at 47% in 2003 and ending at 43% in 2019. The second most significant means are the buses of DPMB, carrying and stagnating around the level of 27% throughout the period. Similarly, the share of trolleybuses is stagnating around 10%. Bus transport at the regional level within the Integrated transport system in SMR in terms of the number of passengers transported is increasing from the original share of 11% to 15% (however, it reached this level in 2010 and has been rather stagnant since then). Similarly, rail transport has grown from 4% to a final 5%, or from 5% to 6% with the inclusion of inter-regional rail transport. Similarly to the growth of international rail transport at the national level, a more detailed look at passenger transport shows that rail transport to other regions has grown by 65% in SMR since 2003, while intra-regional rail transport has grown by 46% and bus transport outside public transport by 39%.

In terms of the number of passengers transported, public transport in Brno remains the key element of public transport in the South Moravian Region, however, it has been growing very moderately by about 2% in the whole period since 2003, while public transport outside public transport, i.e. regional and interregional, has been growing by almost 42% in the same period. This is evidence of the growing role of regional transport, which corresponds to national trends, as it is regional transport systems that provide services and connections to their significantly growing regional centres as a result of metropolitanisation processes. Significant improvements can be observed in the region's weekend and public holiday service, where bus service has increased from 6,000 to 8,000 connections to 14,000 to 16,000 connections from 2000 to 2014.

In addition to the above-mentioned growth trends in rail transport, it should be added that at the level of interregional transport, the dynamic growth is mainly driven by a significant increase in the number

of passengers transported between the South Moravian Region, or Brno, and Prague, where a roughly fivefold increase occurred from 2010 to 2019. In this respect, several possible causes should be considered, including the strengthening of competition on this line as part of the liberalisation of the rail market, but also the ongoing repairs to the D1 motorway, which have put IAD transport at a certain disadvantage. However, it cannot go unnoticed that competition not only on the railway but also intermodal competition between trains and buses has had a significant positive impact on this most important internal rail market for long-distance passenger transport. Student Agency has been actively developing its services here through bus transport and, since 2016, also through RegioJet for rail transport. All this was of course accompanied by a competitive response from ČD, which reacted through its pricing policy and the quality of its services already at the time of intermodal competition with buses before 2016 and continued to do so after that year. A very interesting observation is therefore that this important market for long-distance passenger rail transport has managed to grow several times in a single decade just through the introduction of competition and improvements in service quality and pricing policy, without any significant increase in the speed of transport on this route. This confirms, among other things, another trend in the growing importance of intermetropolitan transport, which underlines the fact that estimates of future transport trends will depend on whether regional centres become strong metropolitan areas or stagnate as mere regional centres in the shadow of their surrounding metropolitan areas. The growing rail traffic between the individual regions is also reflected in a change in the trend in relation to the Vysočina Region and the Zlín Region in particular, where there has been a renewed increase since 2017, as until this year there were significant decreases, especially in the Vysočina Region. Relatively significant growth in interregional rail transport is also recorded in the relationship between SMR and Pardubice Region (Transport Yearbooks, 1998-2019).

2.2 PASSENGER TRANSPORT - CURRENT TRENDS

Since the introduction of jet aircraft, high-speed rail and containers in the 1960s, there has been no fundamental technological change in transport that has fundamentally affected the operation of passenger and freight transport systems. The early 21st century is thus an era of dominance of cars and trucks in surface transport and of aircraft in air transport. These modes of transport and their associated spatio-temporal organisation and functioning of society even hinder the development of alternative modes of transport to some extent (*path dependency*).

Although no major transport technological innovation has taken place in recent decades, the evolution of the modes of transport represented in the passenger transport market has certainly not stopped. The following text will therefore present the main key trends currently occurring within the different passenger transport modes.

2.2.1 Passenger cars - individual car transport

The following, often overlapping trends can be observed in car transport at present and can be expected to continue in the coming periods:

- Partial or full automation of vehicle operation (Fraedrich, Beiker, & Lenz, 2015), which can concern both the vehicles themselves - autonomous cars and self-driving (*driverless*) systems (Burns, 2013), and the management/safety of their operation on roads, such as automated/smart roads/highways (Vasirani, Ossowski, 2012).

- The development of traffic flow management systems (development of telematics and navigation systems), which can contribute to reducing congestion and also to facilitating/speeding up/streamlining logistics operations.

- Changes in the way cars are powered - electric vehicles (Boulanger et al., 2011, Morton et al., 2017), hybrid vehicles (Bauer et al., 2015), biofuels (Alam et al., 2017), hydrogen (Verhelst, Wallner, 2009) - fuel cells, batteries (Romm, 2006).

- Deprivatisation of automobility (Dennis, Urry, 2009; Wright, Nelson, & Cottrill, 2020; D'Urso et al., 2021) - a broader socio-economic trend of a shift from car ownership to car access (the availability of the service by means other than its users owning it) (Benkler, 2004). Systems development may be a way to do this:
    - *carsharing* - carsharing started after the Second World War through the formation of car clubs and thus has a long history (Chan, Shaheen, 2012);
    - *carpooling* - carpooling has a long history since the early days of automobility, and this mode of transport has seen a period of decline, for example in the USA in the 1990s (Ferguson, 1997). However, in the last decade it has become a more popular mode of transport again, often motivated by the congested transport infrastructure for IAD in metropolitan or agglomeration areas (Correia, Viegas, 2011);
    - Both of these systems together can help to reduce the rate of motorisation and thus reduce the number of cars, both those moving on the road (reduction of traffic volume, reduction of congestion) and those at rest (parking);

- Dennis and Urry (2009, 247): *We could hypothesize the payment for access to travel/mobility services will supersede the owning of vehicles outright. [We could hypothesize that payment/costs for access to travel and mobility services will replace vehicle ownership outright*];
- However, there are also critical views that e.g. car sharing will not actually grow at the expense of individual car use, but at the expense of public transport (Pakusch, Stevens, Boden, Bossauer, 2018).

- A number of other measures/transport and mobility policies that are being introduced at national/regional/city/metropolitan level to reduce intensive car traffic (promotion of public/urban transport, paid/resident parking schemes, sustainable mobility plans, polycentricity - 15-minute city, etc.).

- The development of the phenomenon of *automobility* (Urry, 2007; Sheller, Urry, 2000; Featherstone, 2004) - the commonness/normality/habit of car use in everyday life. By being a common and also frequently used mode of transport, the spatio-temporal organization of people's (everyday) life and the organization and structuring of the social environment (commercial and residential suburbanization, desurbanization, deconcentration, ...) adapt to it. The consequence can be the creation of structures that complicate the development and higher intensity of use of transport alternatives.

- Adapting the society-wide environment to cars can also complicate the lives of people without the competence to use a car (people without a car or without a driving licence - more often students, people with lower incomes and education, older people, people with health disabilities). This can even result in their social exclusion, which makes it difficult for them to access places with employment and other opportunities (Cebollada, 2009).

- The overlap of conflicting tendencies in car use:
  - *Peak car* (Goodwin, van Dender, 2013; Klein, Smart, 2017; Stapleton, Sorrel, Schwanen, 2017; Newman, Kenworthy, 2011; Metz, 2013) - a decrease in individual motorization rates, IAD transport performance (passenger-km, vehicle-km), or road traffic intensity overall or at least in a certain part of the day or week, e.g. in the morning rush hour. The phenomenon is statistically registered in selected metropolises/cities and partly at national level (some countries in Western Europe). The existence of transport alternatives and a high population density/opportunity distribution in the urban/metropolitan environment is a prerequisite for the development of the phenomenon. The phenomenon has a complex set of causes (congestion, rising fuel prices, improved public transport supply, urbanism, ageing population, resistance to *urban sprawl*, cultural changes, attitudes, environmental responsibility, growth of e-commerce, etc.). The phenomenon is probably more pronounced in selected age or socio-cultural groups (millennials, young, educated people as carriers of new trends), the question is the transferability of the phenomenon to the whole population and to the whole territory, including peripheral rural areas;

- *hyperautomobility* (Freund, Martin, 2007; Martin, 2009; Hansen, 2017) - a new phase in the intensity of car use in contemporary societies. It is manifested by a continued deepening of dependence on car use, increasing intensity of car use, more regular/daily car trips over longer distances, lower average car occupancy. The trend is characteristic of environments already heavily dependent on cars (USA, Canada, Australia, ...), where in fact there is often no alternative e.g. in the form of public transport. The car is still strongly perceived as a desirable commodity expressing the social status of its owner. The car is also a safe cocoon, a familiar environment, offering the possibility to avoid unfamiliar, strange and threatening environments when travelling between familiar places (*automobility secessionist*, Henderson, 2009; Kent, 2015).

- Motorcycles, mopeds, powered-two wheelers - a cheaper, more flexible alternative to the car (Weinert et al., 2008). Electrification will play an important role in this area, which may develop very significant competition in the form of electric bicycles or electric scooters and other similar alternatives in the urban space.

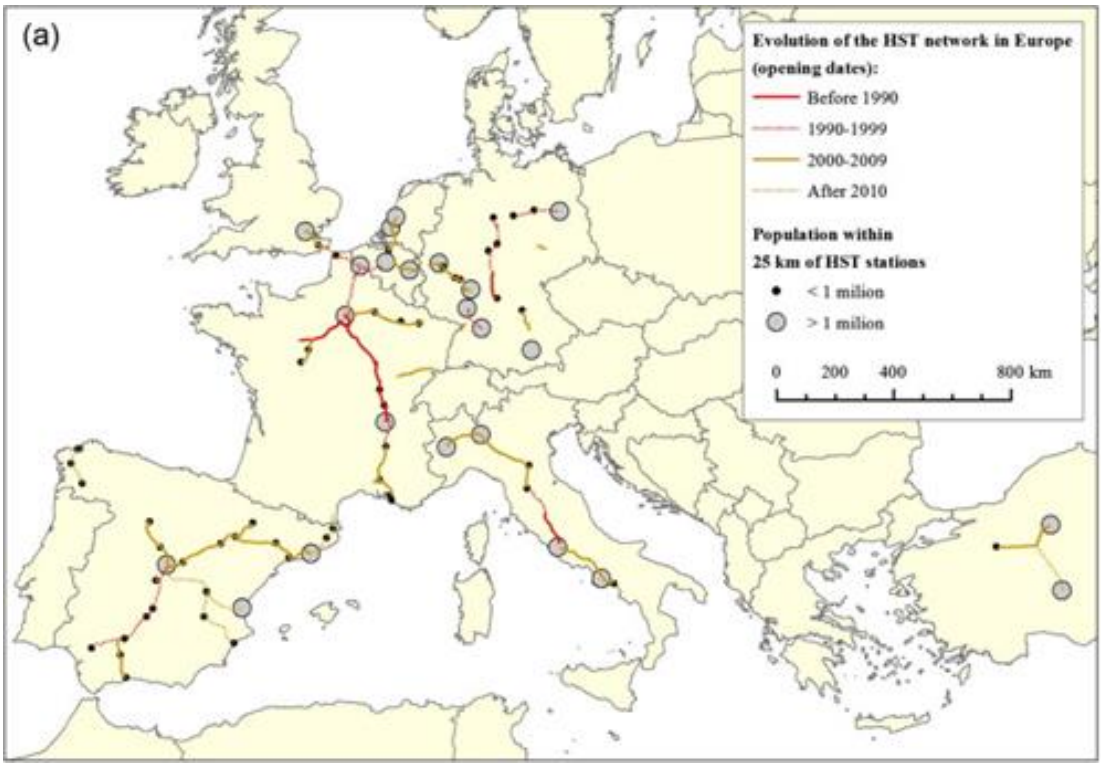
2.2.2 Trains - passenger rail transport

Current trends affecting the number of passengers using passenger rail transport:

- High-speed rail (HSR; Black, 2003; Pearl, Goetz, 2015) - HSR systems are expanding rapidly in Europe (see Figure 15), in addition to East and Southeast Asia (Japan, China, South Korea, Taiwan). Currently, an interconnected international HSR system is gradually taking shape in Europe, extending in a west-east direction from London to Munich/Vienna and in a north-south direction from Amsterdam to Seville/Malaga/Naples. The largest number of international connections on the HSR interconnect cities such as London, Paris, Brussels, Amsterdam, Cologne and Frankfurt (mainly Thalys and Eurostar systems), i.e. metropolises that are part of the European urban core. In spite of the progressive development of the international transport offer, domestic transport is still the clear basis for the high-speed rail offer, and there are also considerable differences between the major national systems within Europe, due to the different geographical conditions, both in terms of infrastructure construction (line speeds, cities served, etc.) and in terms of operation (line routing, stopping policy, frequency, prices):
  - Perl, Goetz (2015, 135): *as the use of HSR technology has spread, it became apparent that more than one formula exists for deploying and operating HSR infrastructure*.

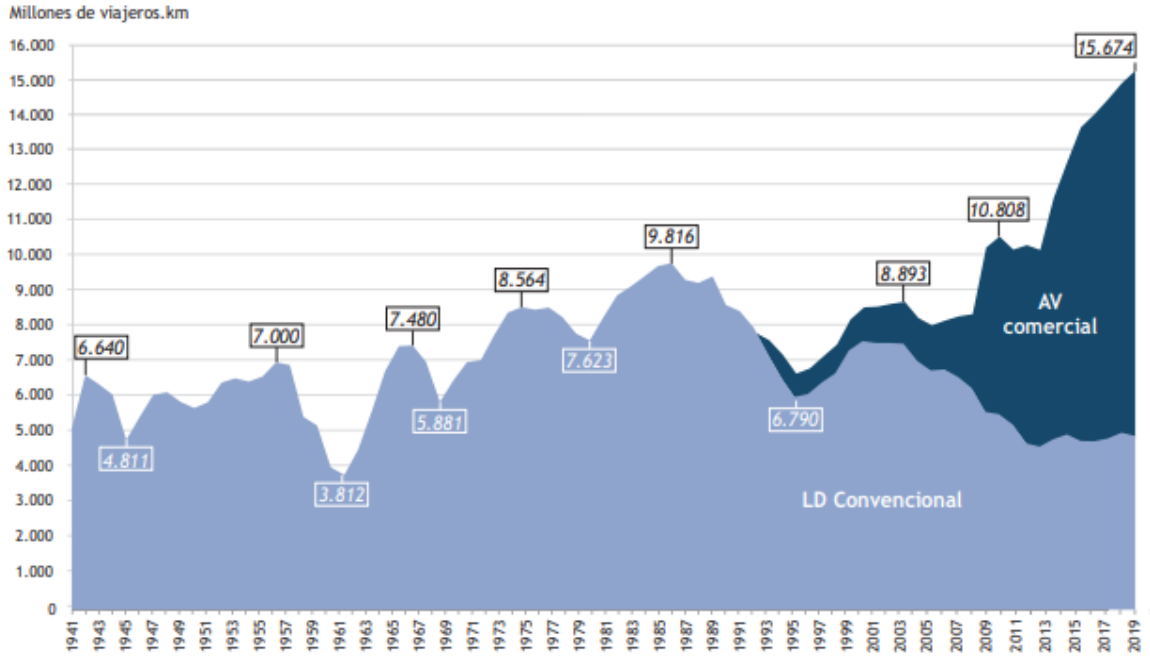
- The development of HSR systems has the potential to increase the number of rail passengers, both at the expense of individual car transport and air transport (Figures 16, 17 and 18). However, the relationship of HSR to air transport is more complex - high-speed trains can replace shorter distance flights on the one hand, while satiating demand for long/intercontinental flights on the other. In line with this idea is the practice in some European countries to build HSR terminals also at major airports - e.g. Frankfurt International, Paris Charles de Gaulle, Lyon Saint Exupéry or Amsterdam Schiphol.

Figure 15: Evolution of the high-speed rail network in Europe



Source: taken from Marti-Henneberg (2015, 147)

Figure 16: Total passenger rail transport performance in Spain by type of service



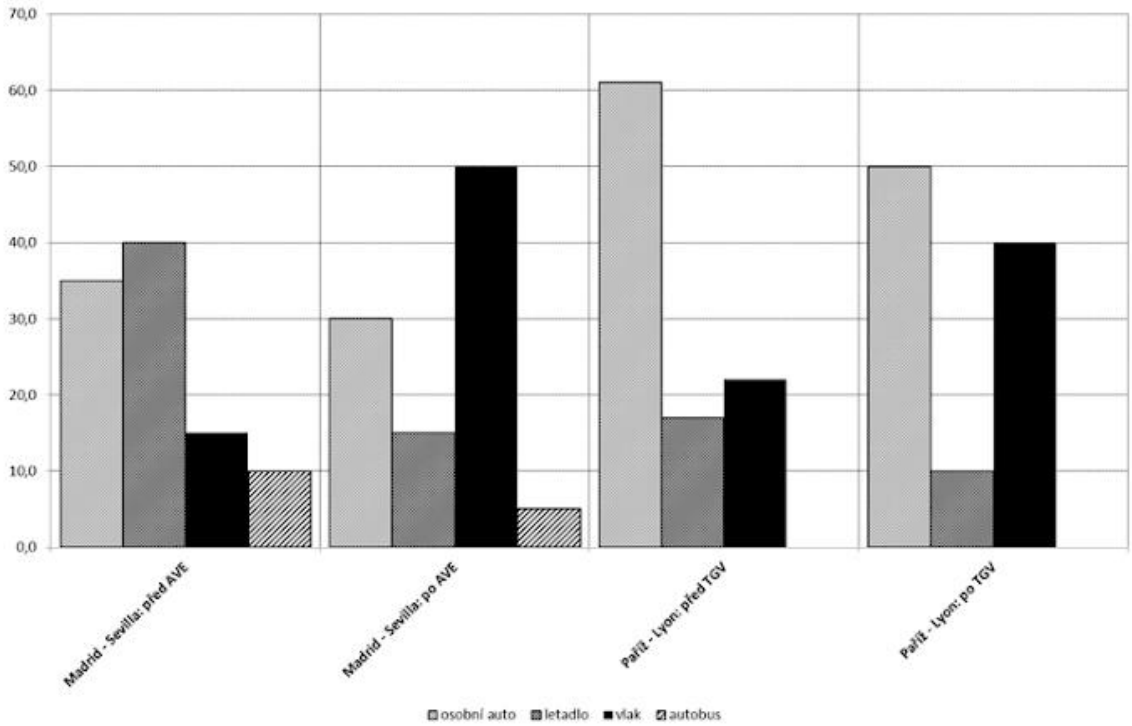
Source:Fundación de los Ferrocarriles Españoles, 2020

- The HSR system is not competitive with individual car and air transport across the board, but only on selected corridors connecting cities/metropolitan regions with sufficiently high demand, which are also located at convenient distances from each other (within 500, 600, 700 km, i.e. within three or four hours travel time in one direction; Perl, Goetz, 2015). The action of the HSR system is thus necessarily and will be selective in space (Knowles, 2006).

- An interesting phenomenon emerging in the context of HSR are the so-called regional terminals, which are supposed to bring the effects of significant improvement of accessibility also to smaller, possibly peripherally located places, which, however, are located in the corridors where HSR routes connecting large cities are routed.

- Liberalisation of the passenger rail transport environment in the EU, either through *open access* (direct competition of railway carriers on selected sections of railway lines) or through tenders for carriers - the process of liberalisation of rail transport has both positive and negative impacts on railway operations. The positive impacts include in particular the potential to offer new services, often at lower prices, thereby increasing the attractiveness of this more environmentally friendly mode of transport and attracting new passengers who did not use trains before. Negative impacts may include, for example, less efficient use of rail capacity, the breakdown of the system offer of the integrated timetable, the orientation of commercial carriers' connections only to profitable market segments (*cherry-picking*), etc. (Tomeš et al. 2014; Tomeš, Jandová, 2018; Kvizda, Solnička, 2019).

Figure 17: Estimated market shares of rail and other modes (%) on the Madrid-Sevilla and Paris-Lyon routes before and after the introduction of high-speed rail

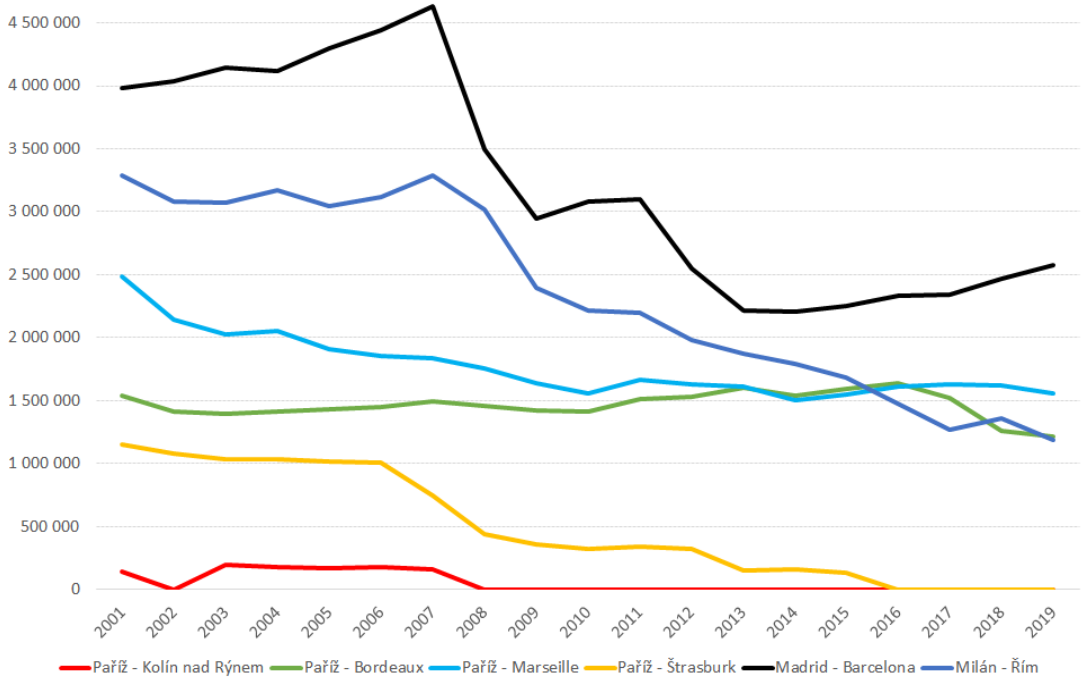


Source: European Commission (2001), European Communities (2003)

- The growth of passenger rail transport in metropolitan regions and in the hinterland of larger cities, the integration of rail transport in such areas into a coordinated system offered in the framework of so-called integrated transport systems (Steiner, Irnich, 2020).

- A relatively sharp reduction in the supply of long-distance night services (Bradley, 2015; Gleave, 2017), although there are some exceptions (e.g. the current activity of the Austrian Railways, *Österreichische Bundesbahnen*).

Fig. 18: Evolution of the number of passengers carried on selected air routes - change in trends in the period after the launch/completion of high-speed rail on the same route



Notes: Paris - Cologne: completion of the HSR line in 2007 (HSL 3 in Belgium)
Paris - Bordeaux: completion of the HSR line in 2017 (LGV Sud Europe Atlantique)
Paris - Marseille: completion of the HSR line in 2001 (LGV Méditerranée)
Paris - Strasbourg: completion of the HSR line in 2007 and 2016 (LGV Est)
Madrid - Barcelona: completion of the HSR line in 2008 (AVE Madrid - Barcelona)
Milan - Rome: completion of the HSR line in 2008 and 2009 (Milan - Bologna and Bologna - Florence sections)

Source: European Union (2020)

- Automation in rail transport - Measures are gradually being implemented in Europe to gradually automate rail transport. This is mainly the ETCS technology, which has several stages and is primarily a first step towards the gradual introduction of more advanced systems (Brandt, 2021): DAS (manual assisted steering) → ATO (automated steering with active supervision) → DTO (fully autonomous steering with control) → UTO (fully autonomous steering without the need for a driver, Brandt, 2021).

- *Magtrain* - this term must be mentioned in the context of the term *hyperloop* below. It is also a technology for magnetic levitation of a train or a means of transport, but in the case of this technology (developed by Nevomo) it is a hybrid model, where magnetic levitation of a train on a conventional railway line can only be achieved by upgrading or modernising it, allowing combined operation on the same infrastructure at higher operating speeds.

2.2.3 On-demand mobility services

A hybrid operating model is gradually emerging in the transport market, which in its essence stands somewhere between a taxi and a private passenger car. *On-demand mobility services* are characterised by:

- better management of vehicle usage in real time;

- the need for fewer vehicles to ensure a similar level of mobility (30-50% increase in vehicle productivity compared to a conventional taxi).

On-demand mobility services can also support the mobility of marginalised groups (e.g. younger people without a driving licence, older people with health problems, people with disabilities, etc.). If people have access to mobility whenever they need it, this may also result in a reduction in the need to own a car and a general transformation of the current design of public transport systems. The public sphere can also be involved in the operation and organisation of *on-demand mobility services*, as this service has the potential to replace or at least complement the existing public transport provision system.

2.2.4 Micromobility solutions

- *Walkability* - creating the conditions for increased use of walking as a primary means of transport in urban environments (Bongiorno et al., 2019, Gupta, Pundir, 2015, Hall, Ram, 2018). Of course, this phenomenon is often linked to healthy lifestyles (Barnet et al., 2017).

- *Bicycle mobility* - creating the conditions for increased use of bicycles as a basic means of transport in the urban environment. The Netherlands, where up to 27% of all journeys are made by bicycle, is a model in this sense, but also many other cities in some European countries (Black, 2003, see also Table 1).

- (Shared) micro-mobility transport (bikes - bikesharing, electric vehicles, scooters, ...) - transport means of this kind are nowadays both reliable and affordable thanks to developing technologies (Landis et al., 2004). Their greater diffusion can bring, especially in urban environments, a relatively large change in mobility habits - thanks to their accessibility, flexibility and space-saving nature, they can contribute to a lower intensity of use of both private cars and public transport:
    - scooters and electric scooters - the advantage of micromobility devices is often highlighted as their energy efficiency (Weiss et al., 2020), while the disadvantage may be their lower safety (Chapman, Webber, O'Meara, 2001);
    - bicycles, e-bikes and bike sharing - in this context, the influence of weather, topography or type of development is also important (Faghih-Imani et al., 2014), but electrification of bicycles can partially offset these potential local disadvantages. Planning or logistics of return flows of these micro-mobility assets is also a significant challenge, as these are often temporally and spatially unbalanced (Nair et al., 2013).

-

Table 1: Proportion of trips made by bicycle in selected European cities

City	Country	Share	Year
Groningen	Netherlands	39	1990
Nakskov	Denmark	35	1995
Munster	Germany	34	1990
Cambridge	United Kingdom	34	1995
Vasteras	Sweden	33	1981
Utrecht	Netherlands	32	1995
Erlangen	Germany	30	1990
Amsterdam	Netherlands	28	1990
Oulu	Finland	25	1995
Freiburg	Germany	22	1996

Source:Black (2003)

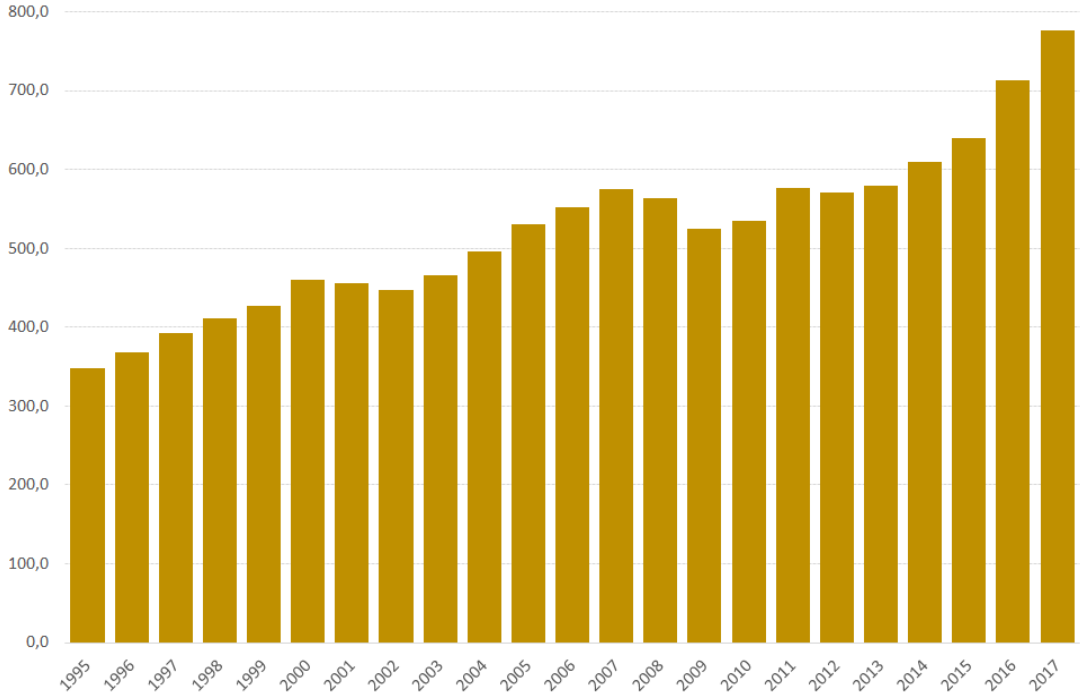
- On micromobility systems, walking and cycling, it is also worth noting that their development is often discussed in relation to their potential to reduce car traffic. Therefore, especially in city centres, the promotion of the development of these micromobility systems in various scenarios and visions is often accompanied by the regulation of automobility, e.g. through parking prices, low emission zones, speed limits, etc. Tight et al. (2011) present three different scenarios for the development of these systems, depending on the radicality of the restriction of automobility in city centres. However, it is necessary to emphasise mobility in urban centres in this context, as micromobility systems cannot be considered as a direct substitute for automobility as a whole.

2.2.5 Air transport

Within the passenger air transport segment, the following significant trends can be identified:

- In recent decades, air passenger transport has been one of the fastest growing modes of transport, with both demand (Figure 19) and supply growing rapidly (Figure 20 illustrates the development of the situation in Central Europe in the post-1990 period). This development is largely determined by:
    - changes in the air transport sector itself - technical innovations, growth in aircraft capacity, falling unit costs (Bowen, 2010; Knowles, 2006), liberalisation and deregulation of the civil aviation sector in many parts of the world associated, among other things, with the emergence of so-called low-cost airlines, which are oriented towards lower prices for the services provided (Burghouwt, 2007; Graham, Shaw, 2008; Dobruszkes, 2006);
    - as well as lifestyle changes leading to greater numbers of people now using air travel as a routine, and sometimes almost daily, part of their lives.

Figure 19: Development of air transport performance in the EU-28 (billion passenger-kilometres)



Source: European Union (2019)

- Combined, these changes lead to a significant increase in air transport accessibility, both spatially and financially. Thus, with some exaggeration, it can be said that, at least in areas of the Western world, air travel is now available to almost everyone, almost everywhere (Button, 2004).

- These trends lead many experts to describe the relationship between air transport and the lifestyle of contemporary society with the term aeromobility. This term reflects the routine nature of the use of this mode of transport in a number of common activities (work, leisure and tourism, education, ...), i.e. the state where the once luxurious mode of transport available only to the social and economic elite has now become a common means of transport, used, among other things, for regular commuting (Zuskáčová, Seidenglanz, 2019):
    - Button (2004, 8): *Air transport networks are an integral and integrated part of any modern society. This is true for Europe and for other parts of the world. [Air transport networks are an integral and integrated part of any modern society. This is true for Europe and for other parts of the world*.]
    - Cwerner (2009, 3): *Is it at all possible to even imagine ... family life, cities, work, popular culture, war, migration, education, leisure, tourism, communication and government (the list could go on) in a world without aviation? Possibly not, so intertwined with air travel modern life and globalization have become. [Is it possible to imagine ... family life, cities, work, popular culture, war, migration, education, leisure, tourism, communication and government (the list could go on) in a world without airplanes? Perhaps not, so strongly are modern life and globalization linked to air travel].*
    - Urry (2007, 3): *it sometimes seems as if all the world is on the move .... The early retired, international students, terrorists, members of diasporas, holidaymakers,*

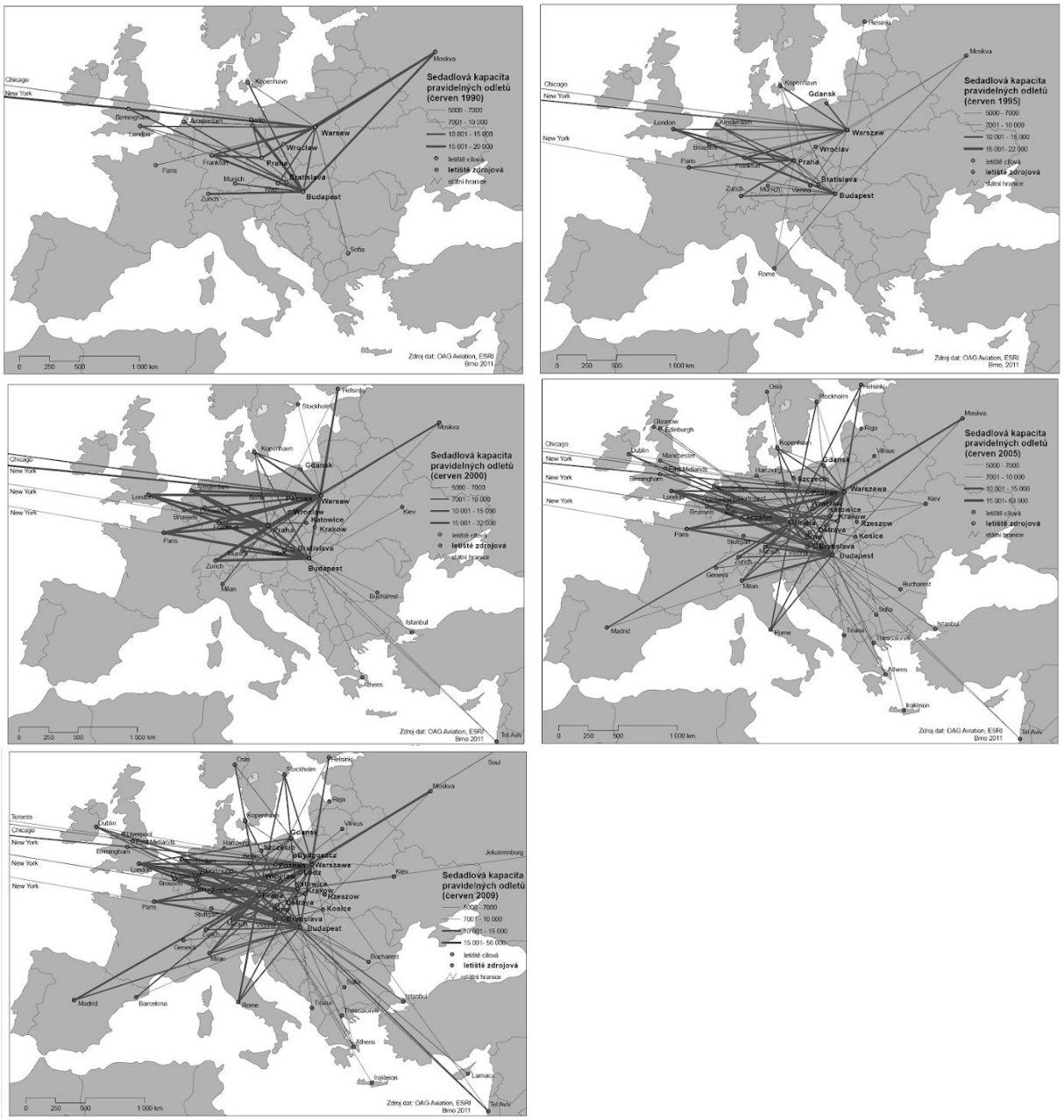
business people, slaves, sports stars, asylum seekers, refugees, backpackers, commuters, young mobile professionals, prostitutes - these and many others - seem to find the contemporary world is their oyster or at least their destiny. Criss-crossing the globe are the routeways of these many groups intermittently encountering one another in transportation and communication hubs, searching out in real and electronic databases the next coach, message, plane, back of lorry, text, bus, lift, ferry, train, car, web site, wifi hot spot and so on. [sometimes it seems as if the whole world is on the move.... vital retirees, international students, terrorists, diaspora members, vacationers, entrepreneurs, slaves, sports stars, asylum seekers, refugees, backpackers, commuters, young mobile professionals, prostitutes - these and many others - seem to think that the contemporary world is their destiny, in which they can go and go anywhere and accomplish anything they imagine there. Across the world, the paths of these various social groups and people occasionally meet or intersect at transportation and communication hubs, where they search real and electronic databases for the next bus, message, plane, truck, text, elevator, ferry, train, car, web, wifi hot spot, etc.]

- However, in addition to its positive aspects, air transport also has a number of negative characteristics, the most significant of which are generally relatively low transport capacity coupled with high energy intensity and therefore high negative environmental impact. Rodrigue (2020) states that air transport was responsible for a total of 2% of greenhouse gas emissions in 1992, and this is expected to rise to 3.5% by the middle of the 21st century.

- *Flightshaming* (Gössling, Humpe, Bausch, 2020; Mkono, Hughes, Echentille, 2020; Becken et al., 2020) - awareness of the negative impacts of air transport, especially in terms of its contribution to climate change. As a direct consequence, passenger numbers are declining, although this is still not a majority practice.

- *Flighttaxi* - it is one of the currently very technologically developing sectors of air transport. However, a significant limitation of this mode of transport is the size of the means of transport offered by this innovative mode, as it is at a level corresponding to the passenger car, which represents a potential in units to smaller groups of passengers per means of transport (Rajendran, Srinivas, 2020). It is therefore more of a complement to transport in densified urban agglomerations or metropolises, but the importance of this technology may lie in the connection to more distant high-speed or airport terminals, etc. Some studies have even considered the possibility of using it directly in the context of passenger transport within the airport area (Maharjan and Matis, 2012). In contrast, current technologies and services of this type are more likely to be used for remote areas - e.g. in Alaska, the underlying current objective is to increase safety and decrease the energy intensity of operations (Thomas et al., 2000).

Figure 20: Skeleton of air routes starting in the Czech Republic, Slovakia, Poland and Hungary; evolution in the period June 1990 (first row left), June 1995 (first row right), June 2000 (second row left), June 2005 (second row right) and June 2009 (third row)



Source: database OAG Aviation

2.2.6 Other transport innovations in long-distance passenger transport

- *Maglev* - the advantage of frictionless wheel/rail operation, speeds of 500 to 600 km/h achievable, the technology can be used as a potential replacement for conventional high-speed rail or as an alternative in countries without conventional rail infrastructure. The system is in operation in Shanghai, China (connecting the city and Phu-tung International Airport), and the *Chūō Shinkansen* line in Japan (a new Japanese high-speed link between Tokyo and Nagoya) is also under construction. In the context of this technology, it must always be

considered that, unlike high-speed rail, maglev cannot use sections on a conventional line in addition to special infrastructure; the system always requires a complete and completely separate infrastructure. A possible comparison of maglev with high-speed rail compatible with conventional rail lines still tends to favour high-speed rail when considering various transport, technological and economic criteria (Janic, 2003).

- *Guided tube concept* (*hyperloop*) - capsules/capsules moving in a partially pressurized pipe. The idea of a vacuum or extremely low-pressure pipe, sometimes called a *vactrain,* for transporting capsules with cargo or passengers has been known to mankind for more than a century. As early as the 19th century, Michele Verne (1895) described this possibility of transport across the Atlantic Ocean at speeds reaching 1800 km/h. In the course of the 20th century, these ideas took on more concrete contours, resulting in a futuristic concept for Switzerland in 1994 (Jufer, Perret, 1994). It was only after 2000 that companies began to emerge that started real development and testing of such technologies, with the goal of replacing short and medium-haul air transport with a more environmentally friendly technology playing a significant role in this respect. Initiatives and companies active in this area include *EuroTube*, *TransPod*, *Zeleros*, *Virgin Hyperloop*, *Hyperloop Transportation Technologies*, *Nevomo* and *Hardt Global Mobility*. Neef et al. (2020) consider hyperloop technology as one of the potential revolutionary changes in long-distance transport that can have significant impacts on both passenger and freight transport, which reflects the perceptions of the respondents in their study (Neef et al., 2020). At the same time, more specific studies are already emerging that are essentially preliminary feasibility studies of this potentially revolutionary technology on selected links. For example, for the San Francisco-Los Angeles connection at a distance of 615 km, travel time is estimated at 35 minutes (Voltes-Dorta and Becker, 2018; Hansen, 2020). Overall, the intensity devoted to such research and studies is also increasing in professional circles (Gkoumas, Christou, 2020).

- Use of suborbital flights for long-distance passenger transportation - Since the 1960s, there has been a fairly significant shift in space exploration, accompanied by advances in transportation technologies such as satellite and other systems to Earth orbit. In this context, the last three decades have witnessed a significant paradigm shift in the thinking of the US space agency NASA, which has abandoned some of its own activities (including, for example, the *Space Shuttle/STS Space Transportation System* programme) and decided to move towards the commercialisation of part of the space industry, with an emphasis on the reusability of these vehicles, which has led to the emergence of a number of private companies dedicated to this field (*Space-X*, *Virgin Galactic*, *Blue Origin*, etc.), or divisions of established companies such as *Boeing*). The idea of using suborbital flights for long-distance transport has therefore been with mankind for the last few decades, but mankind's vision in this respect is often much more optimistic than the reality. For example, in 1994 Wyczalek (1994) predicted that within the next decade it would be possible to use space shuttles for passenger transport (approximately 100 passengers could travel distances of up to 10,000 km in 90 minutes or anywhere on earth in 120 minutes).

2.2.7 Virtual mobility

- Virtual mobility and the associated development of phenomena such as *teleworking* or *home office are* often considered as an alternative to physical transport, i.e. as an opportunity that can contribute to reducing the amount of mobility and thus lead to a reduction of other negative phenomena associated with high intensity of personal transport (congestion, parking problems, environmental impacts, etc.). A paradigm shift in the perception and differentiation of virtual and physical mobility comes with the generation of millennials, whose mobility behaviour is very different from previous generations (the change in their value attitudes can explain up to 50% of the decrease in the need to drive in the US, McDonald, 2015). Conversely, Musselwhite et al. (2015) highlight the importance of this phenomenon in changing the quality of life of older generations. This phenomenon is also linked to the very progressive development of virtual reality, which in the future will make it possible to simulate in a very plausible way different environments and, consequently, experiences for which one has had to travel so far (Kim et al., 2019).

- The theses mentioned in the previous bullet point are true to some extent, but the expectations of the real impact of virtual mobility on the reduction of physical mobility are rather overestimated, as the relationship between virtual and physical mobility is, in the opinion of many authors, more complex (Warf, 2000). In fact, research shows that people who use *teleworking* or *home offices* to a greater extent in their work are more likely to lack intensive personal and social contacts, and as a result, they are more likely to engage in physical mobility motivated by maintaining and strengthening social contacts (visits to relatives, friends, acquaintances, entertainment, trips, leisure, etc.). This may also result in a de facto increase in physical mobility, as such journeys, although less frequent than regular commuting, may cover greater distances. The possibility of replacing regular commuter journeys with irregular long-distance journeys can therefore be expected. Changing these work habits also has an impact on the external costs caused by transport, which may be another motivating factor for *home office* use (Van Lier, 2014). At the same time, it can be said that online forms of shopping behaviour are already being used, for example, but are not yet causing visible or observable decreases in traffic flows to shopping centres, but with the growing importance of these online retail services, such changes may be observed in the future (Suel and Polak, 2018).

- Moreover, mobility motivated by maintaining and strengthening social contacts is more likely to be carried out by forms of individual transport (especially by car, Neef et al., 2020) due to its irregularity and more frequent implementation in leisure time (evenings, weekends, etc.). Its provision by public transport is therefore more complicated than in the case of regular and routine commuting.

- The long-term rise in the importance of leisure mobility (see Table 2) is a clear fact in many European societies (Pooley, Turnbull, & Adams, 2017), and among other causes (e.g. lifestyle changes, increasing wealth and affluence, access to individual forms of mobility, etc.), this phenomenon will certainly be related to the rise of the virtual mobility phenomenon in recent decades.

Table 2: Changes in personal mobility, Great Britain, 1965-1999/2001

Indicator	**1965**	**1975/76**	**1985/86**	**1992/94**	**1999/2001**
Average passenger transport distance per year (km)	5 882	7 627	8 555	10 360	10 965
Average transport distance per trip (km)	5,0	8,2	8,4	9,8	10,8
% of trips made for the purpose of:					
Thesis	39,3	30,0	20,5	18,7	18,7
Education	7,0	7,3	7,5	6,4	6,6
purchase	12,7	16,6	20,5	21,4	21,0
Entertainment	4,8	3,8	4,0	3,8	3,7
social activities	14,3	16,8	18,7	17,8	17,6
Sports	1,6	2,6	1,9	2,1	2,5
other personal matters	7,2	8,9	9,5	10,2	10,3
% of journeys made by mode or means of transport:					
walking	x	34,8	34,2	29,1	25,8
walking (except for routes shorter than 1.6 km)	12,1	13,0	x	x	8,1
round	7,6	3,2	2,4	1,7	1,6
IAD	40,1	45,8	50,5	58,7	62,6
bus	32,9	11,6	8,3	6,6	5,8
train	7,4	1,6	1,8	1,6	2,0

Pooley, Turnbull, Adams (2017)

- The development of information and communication technologies (ICT) and the availability of various online solutions have, among other things, contributed to the advent and development of globalisation and, with it, the shift of many activities outside the former economic core (routine production activities, back offices, ...). Thus, ICTs have actually contributed to a very significant increase in the physical mobility of economic elites, which, moreover, are often carried out over very large, intercontinental distances (Derudder, Witlox, 2016).

- The role of face-to-face meetings remains irreplaceable in the business environment, as issues that virtual mobility has not yet been able to transfer and mediate (co-presence, body-language, emotions, feelings, personal charm, charm, etc.) are also important when concluding large contracts. Thus, virtual mobility functions more as a complement to physical mobility, it can replace face-to-face meetings in the case of routine meetings, but not yet in the case of key meetings - it cannot yet function as a substitute for physical mobility and air transport in particular (Denstadli, Gripsrud, 2010).

- At present, however, the COVID-19 pandemic can be seen as a very strong factor stimulating the increased use of online tools to secure routine work and other activities at a distance.It can be speculated that the increased use of these forms of virtual communication will remain even after the current restrictions on physical mobility are lifted, as many users of these online services and platforms have now become accustomed to them and have begun to use them routinely. Therefore, the use of these tools as a substitute for physical mobility, e.g. for

business and business travel by different modes of transport, will certainly increase in the future.

2. FREIGHT TRANSPORT

The following text will first briefly present the general characteristics of freight transport in the South Moravian Region in a historical and geographical context and identify the key tendencies that are manifested in freight transport. It will then identify current trends that have the potential to influence the shape of freight transport in the coming decades.

3.1 THE STATE OF FREIGHT TRANSPORT BASED ON THE ANALYSIS OF STATISTICAL DATA

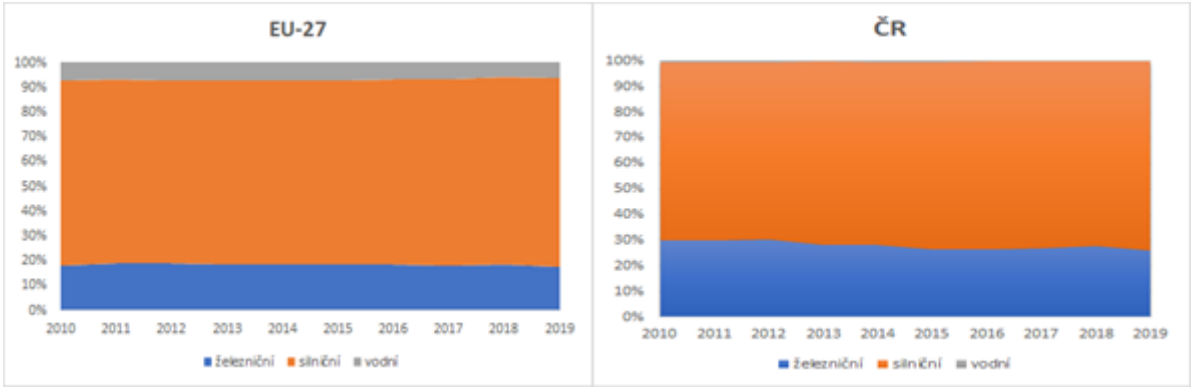
In this subchapter we will focus on general trends in freight transport in the EU and the Czech Republic and then in more detail on the development in the South Moravian Region itself, where attention will be paid in particular to the transport significance of the region in the national and international context.

3.1.1General trends in the EU and the Czech Republic

Figure 21 shows the evolution of *modal* split in freight transport. As can be seen, the split is relatively identical in the case of the Czech Republic as it is for the whole EU-27. The main difference lies in the lesser importance of waterborne transport in the Czech Republic, which is due to the potential navigability of the two dominant rivers (Elbe and Vltava), but also to the lack of infrastructure on Czech rivers and prolonged droughts (Christodoulu et al., 2020; Moravec et al. , 2021; iHned.cz, 2018a). [1]

Historically, the importance of rail freight transport has been higher compared to the EU-27, with a slightly declining share, but still almost 9 p.p. higher than for the EU-27 as a whole.

Figure 21: Division of transport work for freight transport (by tkm)

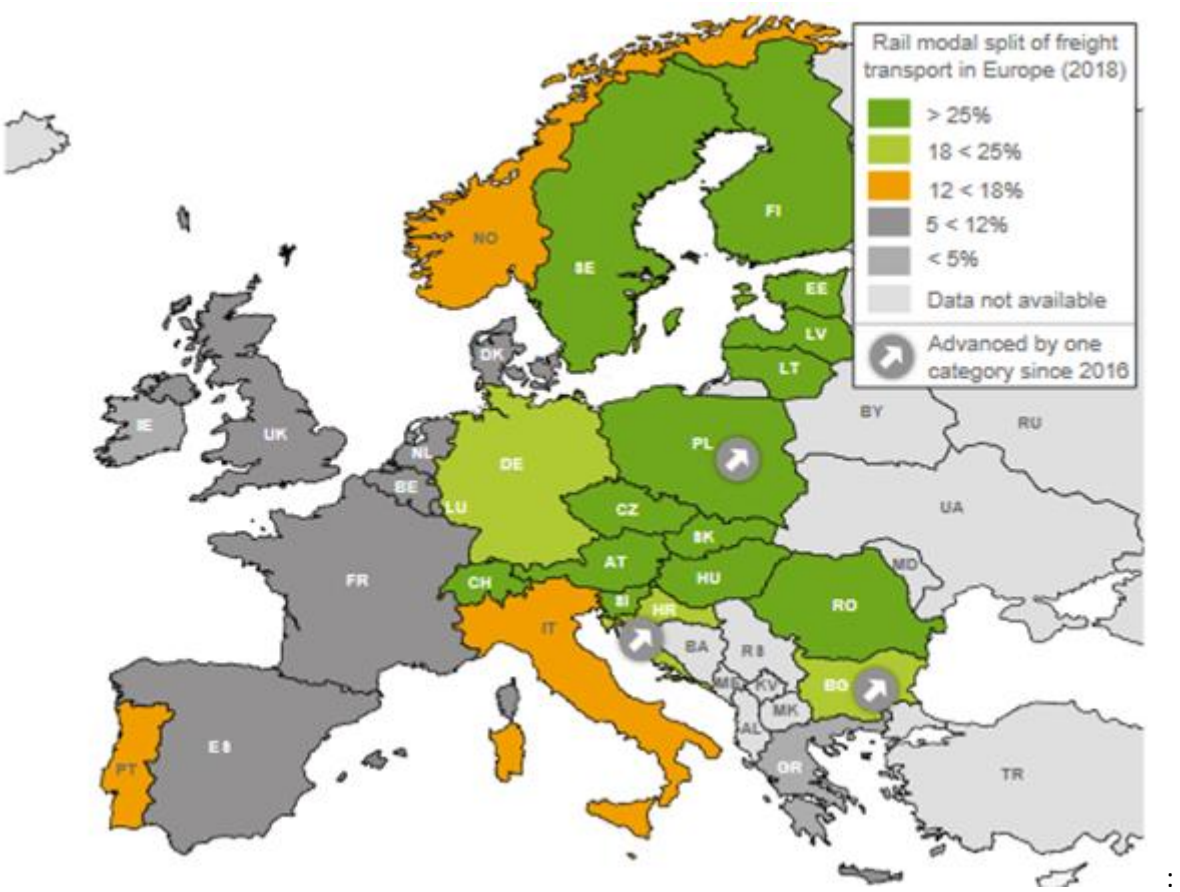


Source: Eurostat database, own elaboration

[1] While in the 1990s nearly five million tonnes of material were transported along the Elbe, today there are only hundreds of thousands (iHned.cz, 2018a).

This can also be seen in the following figure, which places the Czech Republic in a region with an above-average share of rail in freight transport.

Figure 22: Share of rail transport in freight transport (%, 2018)



Source: Eurostat (2021)

In terms of the form of transport, it is interesting to observe the specific type. Although detailed data are only available for road transport, it is possible to trace the possibilities of using individual modes from these data, or the possibilities of multimodal transport, which has its potential and possibility of use, especially in bulk shipments.

Table 3: Types of road transport in Central Europe (2018, million tonne-km)

	Liquid bulk	Bulky Bulk	Large containers	Other containers	Palletized	Suspended	Self-propelled mobile units	Other mobile units	Other
CZECH REPUBLIC	2 002	9 438	1 174	1 377	**19 997**	462	778	c	5 839

Germany	21 889	65 101	37 358	4 958	**111 702**	12 331	6 055	168	46 799
Austria	1 553	7 797	263	486	**7 825**	1 337	293	187	5 229
Poland	11 997	54 513	3 294	17	**135 332**	12 093	6 456	121	92 047
Slovakia	885	11 094	575	524	**19 991**	858	116	24	1 482

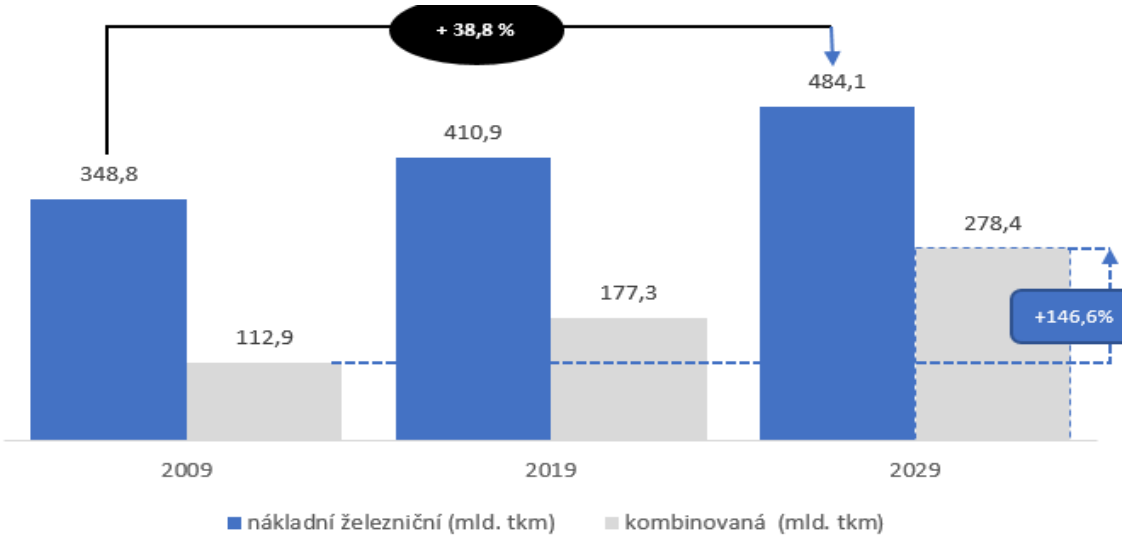
Note: c ... secret
Source: Eurostat (2021)

As the data shows, the dominant segment of the transport market is palletised goods. Its modal history is paradoxical in that in Europe, rail transport was significantly abandoned at the beginning of the 21st century, although it is rail that has led to the widespread use of pallets in freight transport (iHned.cz, 2011). Now this type of cargo dominates road transport, but following the transport policies of the Czech Republic and the EU, it may happen that it will again, at least partially, return to rail. In the Czech Republic, this group accounts for approximately 49% of the production transported by road, which places the Czech Republic approximately in the middle of the countries in terms of its share of total transport.[2] Together with container transport, there is thus significant potential for possible further growth in combined transport. In the Czech Republic, it is mainly shipping containers that are used in combined transport, and to a lesser extent also intermodal semi-trailers and swap bodies (iHned.cz, 2019).

Combined transport in particular has seen significant growth over the last 10 years (55% tkm growth between 2009 and 2019), with cross-border flows being a key factor, increasing by 20% between 2017 and 2019 (UIC, 2020). The use of intermodal transport in the country itself has also been growing, up by more than a third between 2014 and 2019, especially for imports (iHNed.cz, 2019). At the same time, according to the UIC study (2020), the combined transport market in the EU will continue to grow (see Figure 23).

Figure 23: Development of combined transport in the EU

[2] The countries with the highest share of goods transported on a pallet were Slovenia (61.4%), Portugal (60.6%) and Croatia (59.6%), while at the other end of the spectrum with the lowest share were Belgium (27.2%), Finland (30.3%) and Austria (31.3%) (Eurostat, 2021).



Source:UIC (2020), modified

3.1.2 Freight transport in the South Moravian Region

The South Moravian Region is an important transit region connecting the South and North of Europe due to its favourable location in the centre of Europe. The backbone of the freight transport infrastructure is formed by the D1, D2, D46 and D52 motorways, the Brno-Tuřany International Airport and at the same time two main European freight rail corridors - RFC7 Orient and RFC5 Baltic-Adriatic (see Figure 24), which are part of the TEN-T trans-European transport network, pass through the region.

Figure 24: European rail freight corridor network

Source: 2021, modified, Note: RFC5 (Baltic-Adriatic) - dark blue, RFC7 (Orient) - green, RFC8 (North Sea-Baltic) - yellow, RFC9 (Czech Slovak) - light blue

In addition to its geographical location, the transport importance of the South Moravian Region is also favoured by factors generally applicable to the entire Czech Republic - i.e. low wages, qualified workforce, and the presence of virtually all large global and European logistics companies (elogistika.info, 2016). All of this together contributes to the fact that transport performance in the South Moravian Region has been growing in the long term.

If we look at the transport trends in the South Moravian Region itself in the context of the whole Czech Republic in more detail (see Table 4), the dominance of road transport is clearly visible according to the performance of freight transport (as it has already been seen in the pan-European context). As in the case of other regions of the Czech Republic, freight transport within the region itself dominates the performance of the South Moravian Region.

Table 4: Freight transport performance by NUTS 3 in 2019 (thous. tonnes)

	Road freight transport			Rail transport		
	Export of goods to other regions	import of goods from other regions	transport of goods within the region	Export of goods to other regions	import of goods from other regions	transport of goods within the region
Total	**99 354**	**99 354**	**375 488**	**25 001**	**25 001**	**12 298**
Hl. m. Prague	13 425	8 813	16 473	769	1 077	9
Central Bohemia	20 334	22 440	53 835	2 529	5 412	448
South Bohemia	3 861	4 480	29 555	200	728	119
Pilsen	4 512	6 513	27 841	659	1 336	73
Karlovy Vary	1 741	2 539	13 260	2 303	382	1 233
Ustecky	6 598	6 392	30 497	11 340	4 671	2 790
Liberec	4 108	3 992	9 904	141	127	26
Hradec Kralove	7 632	6 397	23 472	629	606	46
Pardubice	7 092	7 364	20 014	1 305	5 978	41
Highlands	4 779	4 952	17 356	542	266	169
South Moravian	***7 341***	***8 563***	***41 678***	***750***	***598***	***200***
Olomouc	8 552	6 371	29 004	961	1 005	254
Zlín	4 133	4 589	14 733	526	1 161	26
Moravian-Silesian	5 245	5 948	47 866	2 347	1 652	6 865
Average	***7 097***	***7 097***	***26 821***	***1 786***	***1 786***	***879***

Source: CZSO (2021)

The volume of interregional transport in the South Moravian Region is slightly above the average of the Czech Republic. The values of intraregional road transport are the third highest at twice the

average of the Czech Republic. In contrast, the volume of rail transport is significantly below the average for the Czech Republic and intra-regional transport reaches only ⅕ of the average values.

In terms of commodities, transport of metal ores and other minerals has been the dominant group for a long time, with a slightly increasing share (by 6 p.p. to approx. 38%). In contrast, the transport of agricultural and food products groups together slightly decreased their share. In terms of transport of the main commodity groups, there is no change in the Czech Republic. [3]

In terms of long-distance freight transport, it is also interesting to observe the position of air transport, which shows an increasing trend in terms of loading and unloading of freight by air within the territory of the Czech Republic (including breakdown by NUTS 2 territorial units) - see Table 5.

Table 5: Air freight transport by loading and unloading in NUTS 2 regions (thous. tonnes)

	2015	**2016**	**2017**	**2018**	**2019**
Total Czech Republic	**58**	**78**	**89**	**91**	**97**
Prague	51	71	82	82	85
Northwest	0	0	0	0	0
Northeast	0	0	0	0	0
Southeast	***5***	***4***	***4***	***4***	***4***
Moravia-Silesia	3	2	3	4	8

Source: Eurostat database

However, as is evident, the growth is primarily concentrated at Prague Airport. To a lesser extent, however, it is also focused on Ostrava Airport, which has significantly surpassed Brno Airport in terms of dynamic growth. In 2018, there was no significant increase in the number of cargo flights, which ranged between 1 and 2 cargo flights per day (iHned.cz, 2018b).

Logistics parks are an important aspect of the past and future development of freight transport within the South Moravian Region and within the city of Brno. The potential of Brno Airport can be increased in the future by one of the most important logistics centres located next to it, which is *Brno Airport Park*. It is connected directly to exit 201 on the D1 motorway, but also has a railway siding, which makes it ready for various combinations of transport modes. To the south of Brno is another major logistics park*, Prologis Park Brno, which is* strategically located on the D52 motorway. Logistics centres are experiencing an unprecedented development, both in Europe and in the Czech Republic, respectively in the South Moravian Region, which was due to the increased popularity of shopping in eshops that need warehouses for their goods (iHned.cz, 2020). This trend was further reinforced by

[3] This is based on data on the detailed commodity composition of transport available for road transport (NST07) in the Eurostat database.

the coronavirus pandemic and the associated further shift of shoppers away from brick-and-mortar stores in favour of online shopping (Novák, 2020).

In addition, there is a long-standing container transhipment facility in Brno (*Terminal Brno*), which has undergone various phases since its establishment in the 1970s in terms of its importance depending on the development of demand for containerised cargo transport. Since 2007, it has been undergoing a revival and is currently thriving due to the high demand for intermodal semi-trailer transport by rail (terminalbrno.cz, 2021).

Fig. 25: Intermodal transhipment points in the V4 countries (2017)

Note: green ... railway (shades = different gauges); red ... road; blue ... water
Source.

The South Moravian Region is by its nature largely a transit region, located on two trans-European routes on the borders of Slovakia and Austria with close access to Bratislava and Vienna. Whether the South Moravian Region's position as a transit region will grow or whether the region will be able to make more of this position is a question of a number of factors, including its ability to cope with current challenges and trends. An overview of current trends in freight transport is presented in the following chapter.

3.2 FREIGHT TRANSPORT - CURRENT TRENDS

Like passenger transport, freight transport is evolving and facing challenges related to modern technology, changes in consumer behaviour and the demands of business customers. Not all trends and influences are the same for freight transport as for passenger transport. Some changes tend to be more pronounced in freight transport than in passenger transport, some less so or not at all, and there are influences specific to freight transport that are not found in passenger transport.

In the following, we mention current trends affecting the freight transport environment. Given its most important role in the EU, the Czech Republic and the South Moravian Region, the main focus will be on road transport. Some of the presented trends have the potential to increase transport performance (mileage), others to decrease (optimise), and for a significant part of them changes with an unclear impact on the volume but changing the currently valid patterns (different type of transport modes, changes in the temporality of transport, etc.) can be expected. A key, but not the only, parameter behind current and future freight transport trends is the evolution or change in consumer behaviour. The various changes in shopping methods, demands for speed and quality of delivery, as well as changes in attitudes towards the environment and life in general, also bring with them pressure to change the behaviour of transport companies. Another significant factor that has the potential to change shipping is technological progress. Whether it is changes to meet consumer or carrier demands, trends related to robotics, artificial intelligence, etc., all have the potential to significantly impact the freight transport sector. It is safe to say that the various trends will be pursued together, to varying degrees and with an unclear overall impact. To better grasp them, we now present them separately, recognising that for some trends the final impact may be different (even opposite) to what we currently expect. The possible final impact of these trends and other broader impacts in 2050 are outlined in the transport scenarios below.

Before presenting the trends affecting the development and structure of freight transport, it is worth taking a brief look at the dynamics of transport trends in the context of the COVID crisis (Figure 26).

Fig. 26: Dynamics of transport trends in the context of the COVID crisis

Source: 2020 11 12 UIC AUHSR New normal.pdf mail Lorand Phillipe (dated 12. 11. 2020)
It is evident that COVID has accelerated trends in many areas, with various overlaps into the transport sector. While much of the impact of COVID will be transitory, some of the effects will be long-term and some have not yet had time to fully manifest themselves. Of particular note is the unexpected shortfall in tax revenues, which risks being reflected in a reduction in government investment spending, and may subsequently limit infrastructure development. In contrast to the increasing demands on freight transport in the context of the development of e-commerce, this is a potentially jarring combination of poorly maintained, undersized infrastructure with a significant burden. However, the question remains how long the COVID effect will last and what the new normal will look like, and what role national governments, the EU and post-COVID recovery strategies will play in reversing/reinforcing the trends. For the time being, the impact of COVID seems rather less important in 2050 considerations, yet in retrospect it will be seen as an accelerator of some changes.

The following overview shows current social, economic, political and technological trends with the potential to influence the freight transport sector.

3.2.1 Trends with the potential to increase transport volumes

1. **Economic growth.** Although the EU aims to decouple growth in road transport performance from economic performance (*decoupling*) and this objective is slowly being met, there is still a direct link between economic growth and transport volumes. It is unlikely that there will be a complete decoupling of economic growth and transport performance in the foreseeable future, or that transport performance will stagnate or even decline as economies grow. [4]

2. **E-commerce development.** One of the main factors behind the development and changes in freight transport, especially on a national and local scale, is the development of e-commerce.[5]The growth in the volume of goods traded electronically entails the **increasing importance of the first and last mile [6]**, which are two crucial stages in the logistics process (SCM, 2018).

3. **Requirement for speed of delivery.** With the growth of e-commerce, consumers are demanding faster delivery of goods and shippers are trying to accommodate this. Shipments that used to take one hour to process are now being forced to be processed in three-minute intervals (or even faster). Among millennials, consumers are willing to pay up to 30% higher prices if goods are delivered the same day; the vast majority are willing to pay extra for delivery at a precise time (Joerss et al., 2016).

4. One of the recent trends is the ***insourcing of*** **last mile logistics. The** growing importance of the last mile and the rapid increase in the volume of last-mile deliveries is motivating shippers to

[4] This could only happen as part of broader societal changes and with a significant change in consumer and corporate behaviour, but this is another trend mentioned below.
[5] In recent years, the development of e-commerce has had an increasing impact on cross-border transport, but the local influence is clearly dominant (SCM, 2018).
[6] First mile - the picking, packing, verification and shipping process triggered by a customer order. The last mile - the final delivery of the product to the customer, whether at home, in the office, at the point of dispensing, or in a smart locker or store via click-and-collect (SCM, 2018).

start making deliveries with their own vehicles, without the use of intermediaries.[7] By using their own transport, they often manage the delivery faster and with full control over the quality of the service provided. The development of own transport, is rather not expected on a large scale, but on a small scale this trend could increase the density of transport in the affected area (Robinson, 2020).

5. The pressure on national, as well as international transport, may be increased by **the construction of large local warehouses for shipments from non-EU countries**, which is related to the introduction of customs duties and VAT for small (until 1 June 2021 under-limit) shipments. A typical representative today is Alibaba (with its Aliexpress platform). However, this trend may not be permanent; with growing awareness of sustainability and a greater interest in local production, these warehouses may gradually disappear after the boom.

6. **Courier robots (robodelivery.** So far, autonomous delivery robots are at the test operation level. Their massive expansion has the potential to congest not only road traffic, but also to increase congestion on other types of roads, such as sidewalks and bike paths. It is planned that as the autonomous driving capability of electric vehicles develops, the ability to robodeliver will become a common feature. The development of robotic and autonomous last-mile services, combined with other influences, may significantly reduce the need for trucking of goods within cities in the future, and in turn increase the transport performance of these autonomous vehicles disproportionately. While autonomous robots would find their application mainly in larger cities (due to the larger number of customers served and smaller commute times), the robodelivery capability of cars has the potential to change the situation on a larger scale. Having the ability to send a driverless car anywhere almost eliminates the need for organized delivery (parcel delivery) and massively increases the demands on infrastructure capacity (instead of 1 delivery truck with 100 parcels it would in extreme case, 100 vehicles would be travelling for 1 parcel). If this method of last mile delivery were to be developed, it would likely increase the importance of sorting hubs on the outskirts of cities and the demands on the infrastructure around them.

3.2.2 Trends with the potential to reduce transport volumes

1. **Decoupling**. The European Union sees decoupling road freight transport from economic growth as a key way to improve sustainability (Tapio, 2005; McKinnon, 2007). It is therefore important to identify the drivers of demand for road freight transport in order to identify possible instruments that can contribute to reducing the intensity of road transport in the future without hampering economic development. Decoupling pressures can have a destimulating effect on long-haul trucking performance (Alises and Vassallo, 2015).
2. **Regulation and taxation.** The freight transport environment is already subject to significant taxation in the form of diesel excise duty, which is primarily linked to negative transport

[7] In the US today, 80% of urban freight transport is self-driven, leading to less efficient use of urban transport infrastructure. The market share of professional logistics service providers is not growing because their services do not meet new customer demands. It is clear that the evolution of transport will be, among other things, the result of being able to align the (complementary) services offered with the requirements of the specific customer segments B2B, B2C and C2C in urban freight transport (Amstel, 2017).

externalities. The EU strategy and vision clearly show that the EU will move towards more environmentally friendly transport. This is in line with the generally stated ambition to make the continent carbon neutral by 2050. Increasing regulation can be expected to take both fiscal and quantitative forms (entry restrictions and bans) and, as a result, will create pressure to reduce freight (road) transport. The EU repeatedly mentions in its strategies that the last and first miles are crucial in terms of climate targets. It can therefore be expected that these sections will be most affected by regulation. Increasing regulation would in turn be an opportunity for rail and intermodal transport.

3. **Clean Air Zones.** Local (urban) transport is already partly affected by the introduction of Ultra Low Emission Zones and Clean Air Zones (Hammadou, Papaix, 2015; Cai et al., 2020), which motivates parcel shipping companies to invest in more zero emission vehicles. Those vehicles that do not meet the emission standards required in the zones will face severe penalties or will be prevented from entering. Development of low emission zones and incentives for the use of clean vehicles Presenting a trend that will almost certainly be applied by more and more cities in the future (Validi et al, 2020). These regulations, combined with digital technologies applied to their compliance control, will clearly increase the demand for zero-emission transport, especially in central and densely populated urban areas, and will increase the pressure to optimise transport and reduce transport performance.

4. **Smart scheduling, IoT, traffic data and Uberfication.** Developments in artificial intelligence, accelerating mobile internet and real-time tracking capabilities, and other trends have the potential to have a major impact on the freight sector (Garcia et al., 2013; Punel, Stathopoulos, 2017). Taraba (Czech Logistics Association, 2021), for example, confirms this: *automation and digitalisation are absolutely crucial. They are simply an unmissable trend., and who is avoiding it?, simply has no chance of survival. Human labour is in many ways irreplaceable, but this is not true for repetitive, routine, physically demanding activities or where human characteristics are a major obstacle to the efficient implementation of processes. However, this does not have to be so-called hard automation or robotization. There are many interesting technologies and solutions that can be gradually deployed relatively easily and with little investment to "eliminate" the negative impact of human resources*. Ludvík Taraba (Czech Logistics Association, 2021) adds: *sThe current pandemic will undoubtedly accelerate the trends associated with logistics. In particular, there will be an acceleration of digitisation, robotisation and automation*.

    a. V Today, most transport planning and scheduling systems are based on the aim of minimising the distance travelled. When delivering in denseé urban areasě but most of the time is spent finding the drop-off zone, walking and actually delivering, not driving. For planning and scheduling, new systems will be developed that use *big data* to predict delivery routes (for tactical planning) and real-time traffic information and availability of unloading zones (for operational planning). Intelligent charging of electric vehicles will be integrated into operations planning. Autonomous mobility will enable plans with an accuracy of units of seconds (Amstel, 2017).

b. Approximately ⅓ of the truck's cargo area is empty on average. This problem is primarily rooted in the fact that current approaches to logistics do not allow perfect optimization. The digitisation of logistics and the involvement of artificial intelligence should significantly reduce this proportion - saving both emissions and costs for companies (Radio Journal, 2021).

c. The "uberisation" of last mile logistics is already happening and this trend seems unstoppable. In urban freight transport, social delivery networks are and will be the leaders of innovation. Sharing capabilities and capacities and joint loading require sharing data with many private and public partners in the supply chain (Amstel, 2017). This development is driven by the growth of regulations on truck entry and deliveries into populated areas. Also evident in US customer behavior is the push for faster and more flexible delivery options with the continued development of the D2C business model [8](Sharma, 2020). The success of companies such as Swedishá *Foodora*, Irish *Deliveroo*, US *Ubereats*, Finnish *Wolt*, locally for example *Let's put food*clearly shows what the current trends are.

3.2.3 Trends changing traffic flow patterns

These trends include such ongoing changes or factors whose influence on transport volumes is Admittedly ambiguous, but but they have the potential significantly altersit traffic patterns. These may be factors that contribute to changing modal shares globally or locally, or changes that bring new transport modes (robots, drones, etc.) into the classic modal mix. We also include some regulatory trends in these trends.

- It is already clear that the **importance of of intermodal transport is increasing, to the detriment of conventional road transport transport.** Many countries, especially in Europe, are investing heavily in infrastructure development intermodal transport. Road and rail networks are being expanded and modernised. As a result, many transport companies can now offer the same transport times for their intermodal freight as for standard road services, taking advantage of the benefits of both modes. First,, the use of intermodal transport offers the ability to respond to customer needs by offering transport terminal to terminal or door to door. Combined transport has the ability to move goods long distances by rail while keeping road transport to the last mile as short as possible. Second, freight volumes are shifted from road to rail through intermodal transportation. This is particularly important for long-distance transport routes, which are severely hampered by congested roads and high variable costs. This makes it difficult for standard road services to compete in favour of new smart and sustainable solutions for intermodal freight transport (Halonen, 2016). The intermodal market is expected to grow by almost 150 percent between 2009 and 2029 (UIC, 2020). Thus, by 2050, this trend can be expected to continue, stimulated by the fact that combined transport contributes to meeting environmental and stra tegic objectives of the EU. Like any industry,

[8] D2C stands for direct-to-consumer, meaning a company that manufactures a product in its own facility and distributes it through its own channels. These channels can include an e-commerce platform, a suite of social media platforms, as well as a branded retail store (https://packhelp.cz/d2c-obchodni-model/).

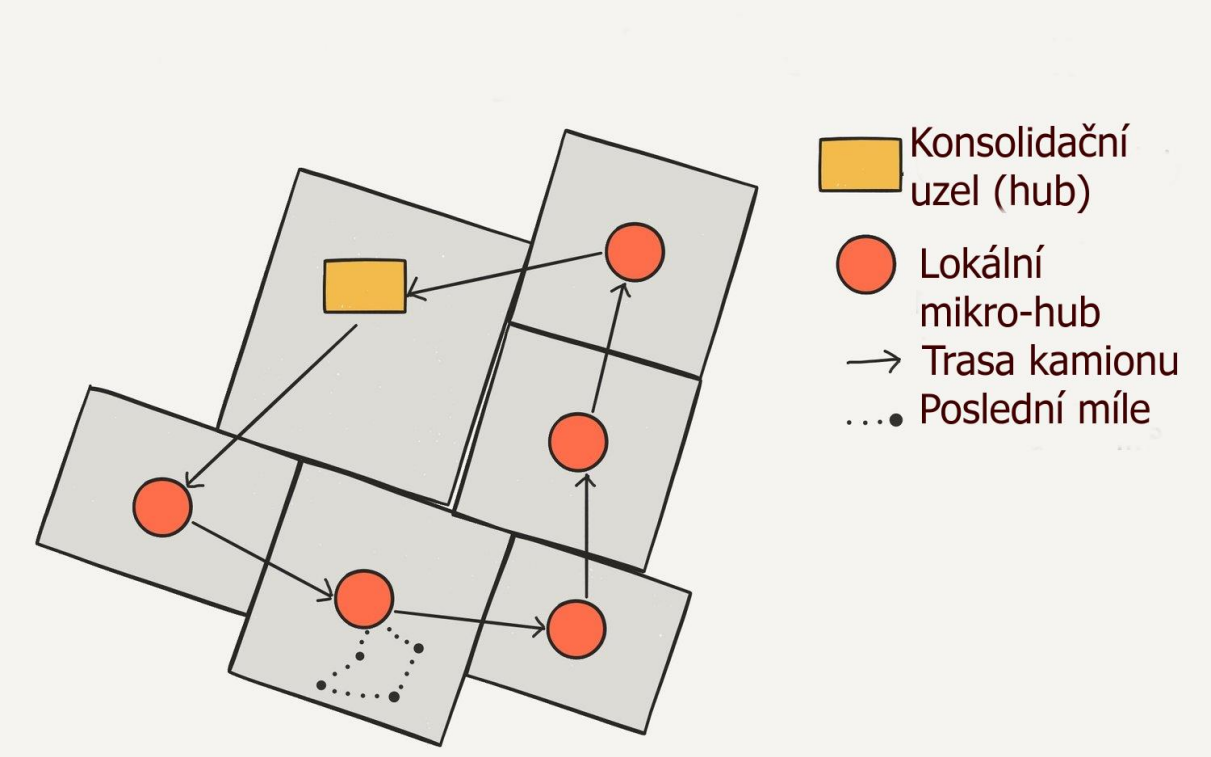
the combined transport sector faces many challenges that affect its behaviour and limit its economic situation (see Figure 27).

Figure 27: Main challenges for combined freight transport

Source: BSL Transportation analysis in UIC (2020)

- Changes are being made to **urban freight transport schemes.** Self-service storage bins are being created and developed, and there is talk of night delivery to reduce congestion during the day, which would allow suppliers to use larger trucks and reduce the number of deliveries If night delivery catches on, the percentage of first full deliveries will increase and overall journey times will decrease as the roads will be less congested (SCM, 2018).
- With increasing pressure on the environment and in the context of urban regulation, **public-private partnerships will develop.** This collaboration will result in urban distribution centres and (micro)hubs where deliveries from multiple suppliers are pooled and sorted, leading to fewer shipments and optimised freight. New possibilities and opportunities for rethinking urban mobility towards "less mobility" of freight and people will be created by the emergence of new residential areas. According to Zetes (in SCM 2018), the use of such centres could save companies 25% per delivery and could reduce delivery-related mileage by up to 45%. In addition, it could reduce vehicle maintenance costs, reduce CO_2emissions, nitrogen oxides and particulate matter and alleviate traffic congestion (SCM, 2018). Customer pressure for fast delivery is also contributing to the development of local distribution centres.

Fig. 28: Schematic of microhub-based citylogistics



Source.

- **Sharing Economy** - The question of the impact of the sharing economy on freight transport does not have as clear an answer as in the case of passenger transport. Despite the growing momentum in the sharing economy, traditional shippers and carriers still face barriers that prevent them from participating in the sharing economy. For shippers, integrating sharing platforms into complex distribution networks is just the first of the hurdles they must overcome. For many of them, maintaining a connection with the customer through delivery touch points is important for cross-selling and up-selling[9]. Shippers will need to figure out how to her , while using shared resources, maintain. In some segments that are subject to stricter regulation (food or chemical industries), the possibility of using shared transport is severely limited. For both FTL and LTL [10]carriers, the use of shared platforms could mean faster movement of shipments. Even in the case of freight transport, shared platforms already exist, One example is a Texas company *Dropoff*which provides courier services. *Dropoff* It uses independent contractors and its own vehicles to transport B2B and B2C shipments, even within the same day. The sharing economy trend is therefore also making its way into freight transport, but the dynamics are much slower and the potential seems smaller than for passenger transport. By using elements of the sharing economy, transport performance should be optimised and savings should be made on the part of companies (Deloitte, 2016).

[9] Cross-selling = selling related goods; up-selling = selling goods in a higher version and/or upgrade or larger quantities.

[10] FTL (*full truckload*) = full load, the truck carries one load that completely discharges it. LTL (*less than truckload*) = partial load, the truck does not fully discharge one load, it can carry multiple partial loads (https://www.timocom.cz/lexicon/dopravni-lexikon/).

- An often talked about and highly potential transport method is **drone delivery**, especially for the last mile**.** The use of drones brings with it significant economic benefits. Given that drones represent a de fac to short-haul air transport, specific in that it does not require expensive or extensive infrastructure, it is not surprising that drones appear in the vast majority of traffic forecasts. Drones can act as a disaggregating force, as their availability and range can create an incentive for people or businesses to move away from dense and expensive urban centres (OECD, 2021). By improving the efficiency of supply chains and offering a new way of transport, drones have the potential to bring a wide range of economic benefits. However, as with all technologies, drones also create economic risks that need to be considered and mitigated to enable their successful development. Consulting firm Roland Berger (in OECD, 2021) identifies four different use cases for cargo drones, depending on the payload of the drone and the degree of autonomy. In all applications, the goal is to automate the transportation of goods to provide a faster, more flexible and cheaper service compared to traditional means of transport:
    - **aautomation of intralogistics** (in factories and warehouses);
    - **Deliveries of medical supplies** (often to remote locations);
    - **dfirst and last mile parcel delivery** (often in and around urban areas): čand often this part of the freight chain is the most expensive and least efficient part of the delivery chain, requiring significant manpower, vehicle numbers and time (especially where poor traffic, bad roads or geography prevent existing delivery methods). Drons can also be combined with other new technologies such as driverless vehicles. Driverless vehicles loaded with parcels could dispatch multiple delivery drones as they approach the most efficient point from which to complete their deliveries. Such a vehicle would serve as a base station for the drones, providing charging and payload exchange as needed (PwC, 2018 in OECD, 2021);
    - **Air freight** (for longer distance applications): cargo drones could allow goods to be transported more flexibly than freight or trainsets; they could also provide an efficient means of balancing stock in different warehouses. For example, an American start-up *Elroy Air* is developing a drone that can carry up to 25 kg at a maximum range of 500 km (Elroy Air, 2020 in OECD, 2021), The company *Yates Electrospace Corp.* (YEC), based in the US, has announced a new broadband cargo delivery drone with a payload of 567 kg (AirCargoNews, 2020 in OECD, 2021), *Natilus*, a start-up in California, is developing a 60-meter drone with a capacity of 100 tons (Jordan, 2019 as per OECD, 2021), In May 2020, the company *Sabrewing Aircraft Company* introduced a drone with a payload of more than 2,000 kg (when taking off and landing from a runway) and a range of almost 2,000 km (Harry, 2020; Hsu, 2020 in OECD, 2021).

Fig. 29: Visualization of AVIDRONE's cargo drone transporting a container

Source: https://www.vision-systems.com/embedded/article/14182481/longrange-cargo-delivery-drones-upgraded-with-collision-avoidance-systems

- **Changes in customer and business preferences towards smart and sustainable solutions**. Behind many of the innovations and modern current trends are the demands of a growing number of customers who prefer smart and sustainable transport solutions. Today, there is a strong focus on environmentally friendly solutions in transport, which is particularly true for intermodal freight transport. Today, there is a growing market for smart and sustainable solutions as well as companies that focus exclusively on environmentally friendly intermodal freight transport. The trend towards sustainability is very evident in the EU. As far as standard road services are concerned, these will always be needed; however, it can be expected that in the future, larger volumes will be transported more by intermodal freight transport, which is likely to be more prevalent in sectors other than the currently dominant automotive and FMCG industries (Halonen, 2016).

3.2.4 Other trends with no single-point impact on transport volumes or patterns

- **Robotics will be the basis for urban freight transport solutions**. Autonomous vehicles will primarily be used for door-to-door delivery, either completely autonomous or accompanying the delivery driver. Unattended delivery by robots and drones, unattended parcel pick-up and delivery stations in offices, shops and public transport stations will find their place. Downstream, robotics will impact the processes of packaging, picking and sorting goods from e-commerce, downstream transportation and containerisation in the supply chain. The trend towards robotics will be amplified by the growing shortage of drivers and changing labour market conditions and will gradually become standard.
- **Electrification** will first affect small vehicles (bicycles, scooters, courier cars), which are already partially electrified. Extension to trucks requires technological advances in battery production and a significant increase in battery capacity.
- Currently, the **transport fleet** is **ageing** - on the one hand, this is a risk for the development and safety of transport, requiring significant capital expenditure for renewal in the near future, while at the same time the need for renewal represents an opportunity for rapid technological

renewal and significant modernisation of the transport fleet and the introduction of the latest technologies that will allow for wider introduction of robotics and optimisation (SCM, 2018).

- The situation that hauliers currently have to deal with **is the shortage and ageing of drivers.** As many as a quarter of the Czech Republic's truck drivers are over 50 years old, while only 15 per cent of those under 30 were young, according to statistics from the Association of Hauliers ČESMAD Bohemia in 2021 (Zelená vlna, 2012). This problem is not specific to the Czech Republic; according to an analysis by the research company Transport Intelligence at the end of last year, there is a lack of European Union in the last year. The situation is worst in the UK. Companies there would be able to employ 55,000 drivers overnight. IN THE CZECH REPUBLICR hauliers lacked around 15,000 drivers at the beginning of 2019 and the crisis is deepening year by year (Váchal, 2019). The covid pandemic and changing consumer behaviour can be expected to exacerbate the problem.

4. SWOT ANALYSIS

4.1 PASSENGER TRANSPORT - SWOT ANALYSIS

S - Strengths	W - Weaknesses
- flexibility and individualisation of the transport market - different passenger preferences - everyone uses their favourite mode of transport - different modes of transport are often used for different purposes - railways - environmental friendliness, safety, reliability, no traffic congestion - the Czech Republic has a higher share of public transport in modal split compared to other European countries - the economic and transport importance of the Brno metropolitan area as the central part of the South Moravian Region within the Czech Republic is still noticeable and noticeable also in interregional transport; this importance is manifested by the growth of the Brno metropolitan area within the South Moravian Region, which has positive impacts on transport accessibility and serviceability in public transport and negative impacts in IAD (congestion - see weaknesses) - high accessibility of public transport throughout the whole territory of the South Moravian Region, increased temporal accessibility of public transport, both on working days and free days (weekends, holidays)	- daily mobility behaviour is largely dependent on private transport provided by private car - the increasing importance of comfort and speed for passengers is not accompanied by a sufficiently rapid change in the public transport offer - the similar emphasis of demand on door-to-door solutions is not accompanied by a portfolio combining public transport with micromobility solutions - the growing importance of metropolitan areas increases the mobility requirements to these centres, this causes traffic congestion - railways - high infrastructure costs - fossil fuel dependent modes of transport (passenger cars, air transport) have a strong position in the transport market - high environmental impacts of the current transport system layout - unintended but significant consequences of the current transport system (social impacts, spatial arrangement of cities and the settlement system, ...) - the peripheral areas of the region in the Znojmo and Hodonín regions are on the periphery of interest in terms of the transport-metropolitan development of Brno

O - Opportunities	T - Threat
- transport automation and a range of alternative drives, telematics and navigation - the potential for the development of transport and mobility sharing systems (in particular carsharing and carpooling, also sharing of other modes of transport) - rail - high speed rail (HSR) and its potential to reduce the use of car and air travel for long distance journeys - home-office and online retail - overall reduction in mobility of the population, potential for transition to virtual mobility - traffic regulation - the potential to modify traffic and mobility behaviour so that it produces fewer negative impacts of various kinds (environmental, social and other impacts) - new technologies - hyperloop, maglev, suborbital flights and others - micro-mobility solutions and on-demand mobility-as-a-service - HSR as a tool to improve transport accessibility of the Brno metropolitan region and through it the whole SMR territory - potential for growth of residential and economic attractiveness within the (Central) European region	- reluctance of residents to change their habitual transport and mobility behaviour - insufficient development of the necessary transport technologies, complications with their implementation, their lack of acceptance by users - regulation of the transport market and mobility behaviour - negative public acceptance, unintended consequences - pandemic experience - concerns about the use of public transport - significant and irreversible environmental, climate and other negative impacts if the transport market continues to operate as it is currently designed - the significantly growing transport market between Brno and Prague can be seen as a certain threat in the future also in relation to the planned development of the HSR, as Prague clearly is and will be a metropolis of higher importance and may mean an outflow of highly qualified workers and services in relation to Brno, who will limit Brno to their residential location - in a similar way as Prague, other (Central) European metropolises may threaten the settlement and regional importance of Brno through HSR (risk of sucking out Brno and South Moravian resources from Vienna, Munich, Berlin, Frankfurt and other cities well connected to HSR networks)

4.2 FREIGHT TRANSPORT - SWOT ANALYSIS

S - Strengths	W - Weaknesses
- the position of the South Moravian Region is strengthened by the location of Brno at the crossroads of Prague - Vienna - Bratislava - (Ostrava) and the crossroads of two TENT-T corridors - the existence of the airport with a connection to the railway siding and in close proximity to the D1 motorway enables Brno to use air transport or combined transport	- marginal capacity of the backbone network around Brno, easy collapse in case of accident/repair. - insufficient capacity of the Svitavy route - unfinished motorway to Vienna
O - Opportunities	**T - Threat**
- modern technologies represent an opportunity for the development of efficient, sustainable and clean freight transport - Brno's location and existing facilities are a promising starting point for development, intermodal and combinedé transporta - due to its location, the South Moravian Region has the potential for further development of logistics parks	- may threaten the position of the South Moravian Region stion of Bratislava and Vienna - Brno airport is not yet in the focus of attention of cargo carriers and competition from neighbouring airports in the Czech Republic and abroad its role may be further reduced - rising land prices may be a limitation for the development of logistics parks as well as for the upgrading and construction of new infrastructurey

5. VISION OF THE FUTURE DEVELOPMENT OF PASSENGER AND FREIGHT TRANSPORT

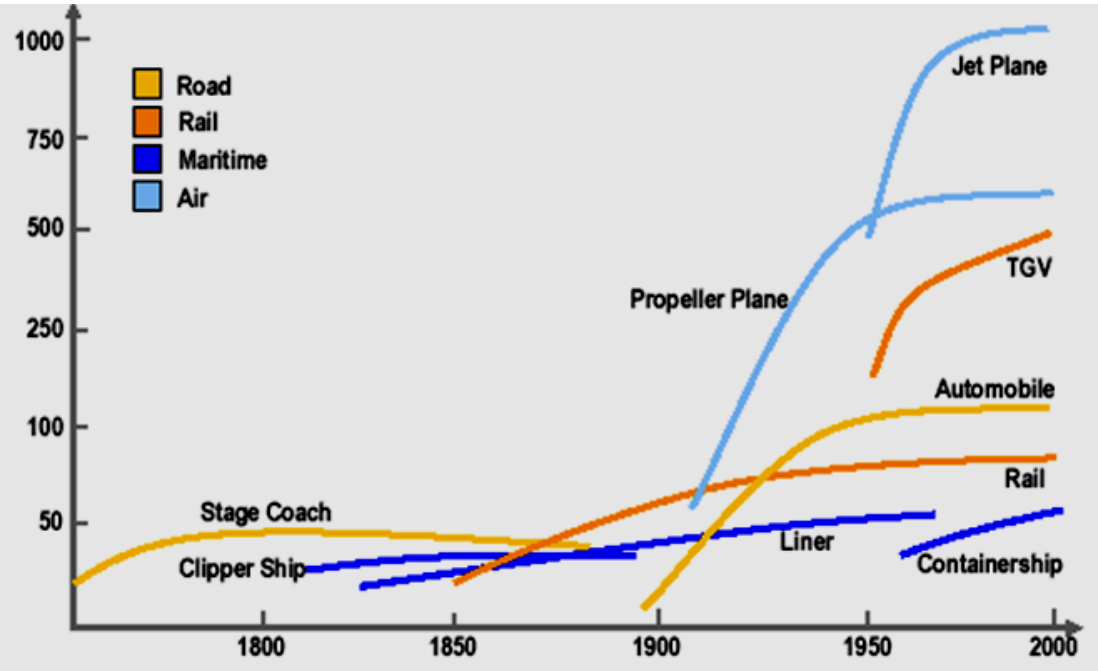
5.1 REVOLUTIONARY AND EVOLUTIONARY DEVELOPMENTS IN TRANSPORT, EXTRAPOLATIONS AND FUTURE SCENARIOS

According to Rodrigue (2020), developments in transport are a combination of:

- Revolutionary changes - in this case, the advent of a completely new transport technology that will fundamentally change the functioning of the transport market. Examples of such changes in transport arrangements include the advent of the steam railway during the first half of the 19th century or the introduction and widespread adoption of the passenger car during the 20th century.

- Evolutionary development - in this case, there is a gradual improvement of existing transport technologies, and thus, for example, an increase in their productivity or their transport capacity, an increase in speed, a decrease in their price, etc. Examples of such transformations include the gradual changes in the functioning of the rail transport system from its inception to the present day (e.g. replacement of steam propulsion by diesel and electric propulsion, introduction of high-speed rail, deregulation of the market and many others), or partial modifications in the functioning of the individual car transport system (new and cheaper vehicles, construction of motorways and other hierarchically superior road routes, electric cars, etc.).

Figure 30: Evolution of travel speeds in transport - the result of a combination of revolutionary and evolutionary changes



Source: Rodrigue et al. (2004)

As a result, estimating the future evolution of transport is a very complicated matter (Rodrigue, 2020):

- extrapolation of trends already known from past developments is possible only for short-term forecasts, up to about 5 years;

- in longer time horizons of up to 10 or 15 years, scenarios of development are necessary, the detail and, of course, reliability of which is necessarily lower compared to trend extrapolations. As the time horizon of the outlook is extended, the level of uncertainty of the forecast logically increases, since in such a case significant and unexpected breaks may occur that cannot be anticipated in advance (possible emergence of new transport technologies, significant changes in economic and social conditions, etc.);

- In the case of a very long time horizon, uncertainty therefore greatly outweighs predictability, and the outlook can thus take on an almost speculative character.

Estimating the future development of transport is a very complicated matter, not least because it is not only a consequence of technological developments relating to the transport systems themselves, but also a consequence of developments in other non-traffic factors. These factors act both independently and in complementarity. In particular, the most important factors that have a strong potential to modify future transport and mobility developments include (Rodrigue, 2020, see also Figure 31):

- Political aspects - public interventions introducing various forms of regulation or deregulation of the transport market, changes in taxes and other charges linked to individual modes of transport; transport requirements resulting from security measures (e.g. airport or bus controls in South America in the wake of terrorism, etc., Zahraei et al., 2019);

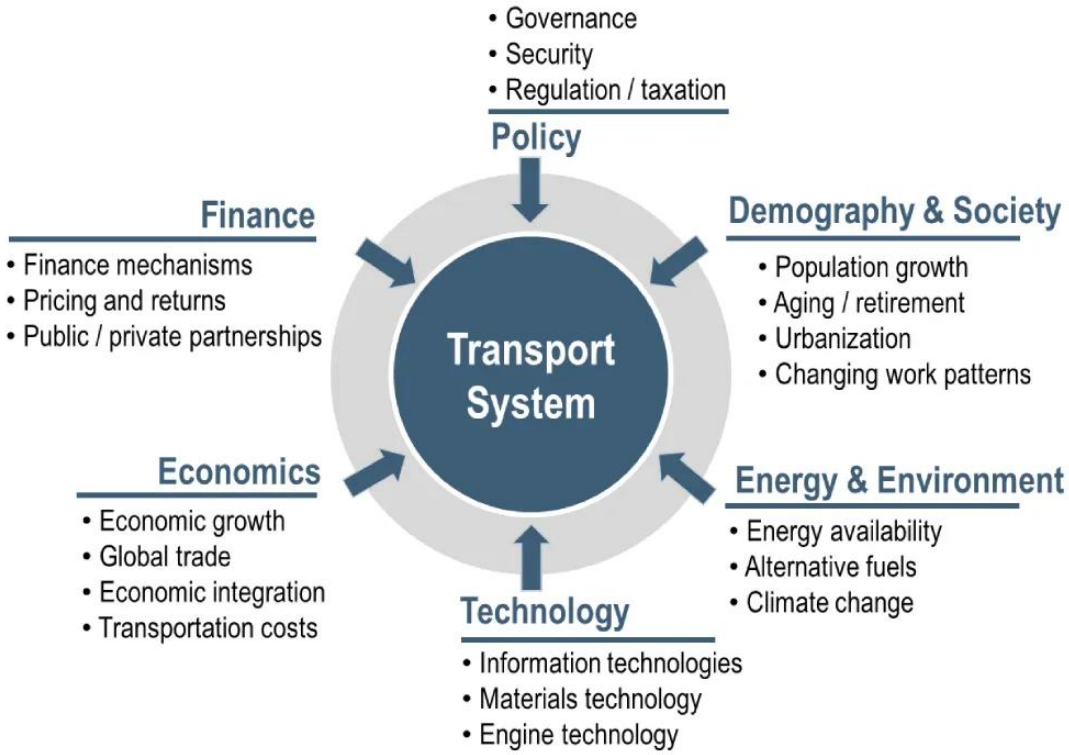
- demographic dynamics and changes in the population structure - population growth or stagnation associated with changes in the population structure both by age (ageing of the population) and by a number of other socio-economic characteristics affects both the overall demand for transport and mobility and, where appropriate, preferences for certain transport modes and mobility patterns;

- energy and environmental aspects - the availability of energy resources, the use of conventional and alternative fuels (decarbonisation, electromobility, etc.) and their (undesirable) impacts on the environment and climate;

- economic aspects - issues of economic integration, internationalisation and globalisation of the world economy and the shaping of e.g. related logistics and distribution solutions; issues of the possibility of (in)separating economic growth and growth in transport demand;

- financial aspects - questions of the amount of necessary and available financial resources required both for the construction and maintenance of transport infrastructure and for changing the way transport and mobility issues are organised and provided.

Figure 31: Drivers of change in transport



Source: rodrigue (2020)

Given that the risks of the long time horizon discussed above and the complexity of the issue are fully understood by the authors of this study, their outlook of the expected transport development until 2050, including implications for the territory of the South Moravian Region, will be a specification of several scenarios.

5.2 RESEARCH ON TRANSPORT SCENARIOS BY POLITICAL ACTORS AND EXPERTS

The basic document that set out a certain basic scenario for the development of the transport sector in the European Union is the 2011 White Paper entitled *Roadmap to a Single European Transport Area - Creating a competitive and resource-efficient transport system*. This document set out the basic contours of the development of transport in the EU, including a move away from oil, the reduction of greenhouse gas emissions, including the development of new fuel systems, and the opening up of the European transport market, which is of course significantly helped by the integration of national systems through common and compatible transport infrastructure, including the removal of formal barriers to the promotion of transport within the EU. In particular, the completion of the European TEN-T infrastructure and the promotion and introduction of multimodal transport solutions and multimodal terminal systems are key. Other important aspects are the promotion of automation through the introduction of the European navigation system Galileo, the improvement of transport safety and the introduction of the *polluter pays* principle, which may have a significant impact on air or road transport in some of the scenarios described below.

In the area of the Czech Republic, it is also necessary to mention the basic strategic framework of transport development, which is of course the *Transport Policy of the Czech Republic 2021-2027, with a view to 2050*. The main objective of the Transport Policy is a relatively general statement on creating conditions for the development of a quality transport system based on the use of technical-economic-technological characteristics of individual modes of transport, on the principles of competition with regard to its economic and social impacts and its effects on the environment and public health. However, this objective has a number of downstream strands that transport policy should address: customer access (taking account of users' needs), transport safety, financial resources for the operation and construction of transport systems, closely related transport infrastructure, support for modern technologies (including space), and the consideration of environmental and social issues in the planning of transport systems. Transport policy is closely linked to other strategic documents. The area of infrastructure is mainly addressed in the *Transport Sector Strategies of the Czech Republic*, in their 2nd phase (2013) updated as of 2017. In order to support alternative micro-mobility solutions, the follow-up strategy is the *National Strategy for the Development of Cycling Transport in the Czech Republic 2013-2020*, which is closely related to transport in urban and suburban areas. Public transport as such is then addressed in the *White Paper - Concept of Public Transport 2015-2020 with a view to 2030*. The process of development of modern technologies, digitalisation and automation is the subject of the *Action Plan for the Development of Intelligent Transport Systems (ITS) in the Czech Republic until 2020 (with a view to 2050)*. The last follow-up strategic document is also the *Air Transport Concept for the period 2016-2020 for the Czech Republic*.

In the study presented by Neef et al. (2020), a rather extensive survey was carried out to identify possible scenarios for transport and mobility development according to the different population groups interviewed. On the basis of this investigation, the significance of the representation of two types of scenarios, namely likely and preferred, was formulated. These scenarios are as follows:

- The infra-economic r/evolution - assumes a prosperous economy, strong growth in mobility and freight transport and a significant expansion of infrastructure. Comprises 5.2% of all probable and 4.2% of all preferred estimates;

- techno-pessimistic r/evolution - the scenario highlights the difficulty of changing mobility behaviour, namely that although technology has changed society in recent centuries, it has not been able to reduce mobility. *In the past, technology created more rather than less traffic: why should this change now* (Neef, Verweij, Busscher, Arts, 2020, 7)? The scenario is based on 16.4% of all plausible and 8.8% of preferred estimates;

- r/evolution of security - quality of life is the central theme of this scenario, which is based on 8.3% of all likely and 10.4% of all preferred responses. Here the authors stress that the most important thing is to spend quality time with friends, family or oneself. It is not a given that people want to work 4-5 days a week, an extended home office is a given.

- Technological r/evolution - scenario represents 11.9% of all probable and 11.2% of all preferred estimates. Technological innovations are assumed in all types of transport infrastructure including, for example, intelligent management of transport components (sections and assets), predictive maintenance, automated operations, intelligent transport, new (e.g. hydrogen fuels) and the use of 3D printing;

- The doomed ship scenario - this scenario is characterised by an attempt to make society more sustainable, but climate targets are still not met in this scenario due to a number of environmental, social and political challenges. The climate is a socio-political issue which in itself hinders the achievement of climate goals due to the emergence of anti-movements. It represents 13.3% of all probable and 9.1% of all preferred estimates;

- hyperloop revolution - the scenario contains 4.4% of all plausible and 6.0% of all preferred estimates. This scenario can be considered a special case of *technological revolution*, but here it is really a case representing not evolutionary but revolutionary changes;

- Green Revolution - in this last scenario, the authors envision the development of a world as environmentally friendly as possible, where fossil fuel consumption and $_{CO2}$ emissions are reduced as much as possible. It represents 5.2% of all probable and 9.6% of all preferred estimates.

For the vision of transport in the South Moravian Region, the role of its regional centre, i.e. Brno, is of course crucial; it can gradually become a regular regional centre of Central Europe or, on the contrary, grow in importance and gradually become a full-fledged Central European metropolis. It is therefore inspiring to give an example of a prediction of the development of a metropolitan scenario. As an example of metropolitan area development, the vision for Singapore in 2040 is presented here, which takes the following forms according to Zahraei et al. (2019):

- A shared world - this scenario represents a radical shift towards a shared lifestyle. Shared mobility is an innovative transport strategy that allows users to gain short-term access to transport without having to own a means of transport. In a shared world, people embrace community living and a lifestyle of shared resources and means with two key aspects: shared mobility and self-sufficient-zones providing a portfolio of needed services on-site;

- Virtual world - the virtual world scenario depicts a future in which virtual reality technology is key to everyday life. In this scenario, Artificial Intelligence (AI) and Internet of Things (IoT) technologies become ubiquitous technologies and change many societal norms. The concept of self-realization is also a significant change. As people have access to a large amount of online information without having to rely on others, they will develop a sense of strong individualism.

The experience with past visions that dealt with predictions for an essentially present state several decades in advance is also instructive. Such an experience is represented, for example, by the 1992 scenarios of Masser et al. (1992):

- Growth scenario - the first scenario shows the most likely development of transport and communications in Europe if all sectoral policies have economic growth as their main objective. It is also likely to be a scenario of high-tech development and a market economy with as little government intervention as possible;

- Equity scenario - the second scenario shows the impact of policies that primarily seek to reduce inequalities in society, both in terms of social and spatial disparities. Where these policies conflict with economic growth, consideration of equity and fairness is a priority;

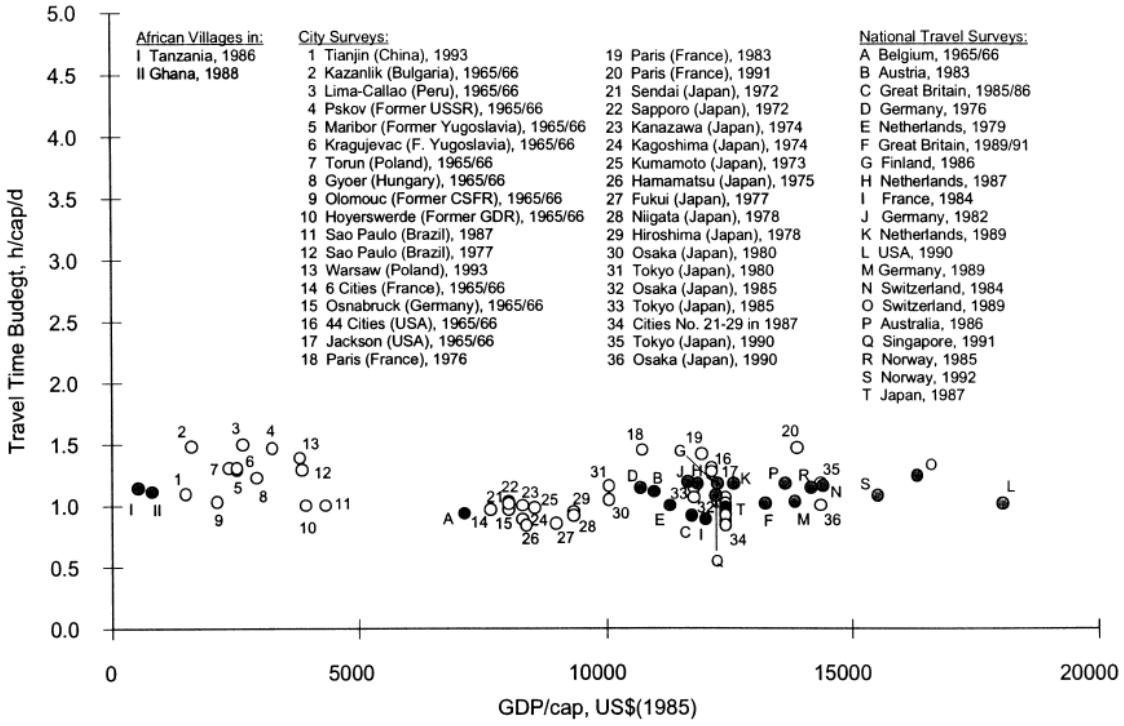
- Environmental scenario - the third scenario emphasises quality of life and environmental aspects. There will be restraint in the use of technology and regulation of economic activity. In particular, where economic activities conflict with environmental objectives, lower levels of economic growth will be accepted.

The above scenarios from the 1990s are clearly a product of their time, as they correspond to different paradigms of economic policy, namely liberal, social democratic and environmental concepts, but consider these concepts to be completely divergent in terms of objectives and methods. However, it is now necessary to revise this view, as many environmentally or socially oriented social innovations are ultimately seen as primarily a significant opportunity for business. Whether through the well-known *rebound* effect in environmental innovations (which ultimately means that the demand for the environmentally innovative product increases to such an extent that its overall environmental impact is higher than that of the original product before the innovation was introduced) or precisely through shared services such as *Airbnb* or *Uber*, reflecting certain social ideas at their birth but developing into standard business.

In relation to the various development scenarios, it is perhaps appropriate to mention some facts that remain stable in the long term despite changes in technology, preferences, and regulatory frameworks. Schafer and Victor (2000) cite time spent in transport for each individual as a key stable element in mobility predictions. This individual daily transport time is called *travel time budget* and according to the authors it is stable despite time and space (which they declare based on the results of studies from four decades of the 20th century, Figure 32). According to their estimates, this travel time budget is around 1.1 hours per day. Although there are some variations in this travel time, e.g. in the case of reduced mobility of the elderly (i.e. according to selected socio-economic characteristics) or according to local differences (commuting through traffic jams, etc.), according to the authors this travel time oscillates around the above value. However, what changes over time, according to the authors, is primarily the income and wealth of society, and as wealth increases, so do the demands on transport

speed, which is reflected in increasing transport distance and therefore increasing transport performance.

Fig. 32: Travel time budget - overview of the results of the research carried out



Source :: Schafer and Victor (2000)

5.3 VISION OF THE FUTURE DEVELOPMENT OF PASSENGER AND FREIGHT TRANSPORT IN THE CZECH REPUBLIC AND THE SOUTH MORAVIAN REGION UNTIL 2050

5.3.1Key groups of factors, axes of determination

From the above discussion and also a brief presentation of the basic principles or ideas from existing scenarios conceived by other institutions/authors, it is clear that the future development of transport will be influenced by a number of sub-factors and facts, which will also strongly influence each other. In an attempt to simplify a complex and complicated situation, we consider the following groups of factors, or rather the axes of determination, to be crucial:

- the degree of regulation/deregulation of the transport system;
- the scope of technological innovation;
- a wide range of other issues with the potential to modify ongoing developments in a different direction.

The degree of regulation/deregulation of the transport system reflects the current tendencies to influence/modify the future development of transport in a desirable direction by public authorities of different levels, from the municipal level, through the regional and national level to the supranational/international level (e.g. EU initiatives) or even global level (global climate agreements, etc.). The regulation of transport systems can of course be motivated by different objectives, but among the most resonant in contemporary society is the regulation of transport supply or even demand in order to reduce their negative environmental and social impacts. Thus, in line with this general formulation, there are both efforts to decarbonise contemporary transport, efforts leading to increased equity and equality in access to transport and transport infrastructure (Schwanen, 2016; Sutton, 2015), as well as activities aimed at ensuring that transport no longer functions *per se* within society, but more as part of a broader stream of activities supporting other policies aimed in different directions (Lyons and Loo, 2008).

The scale of technological innovation will clearly influence the future development of transport, with both the continuation of existing trends discussed in the relevant chapters of this report (e.g. *on-demand* mobility services, autonomous vehicles, electro-mobility, *maglev*, suborbital flights, etc.) and - given the length of the outlook up to 2050 - the emergence of some new, as yet unknown technologies highly likely. IT solutions and technologies for remote control of vehicles and entire traffic flows (telematics, navigation, etc.) will also develop and be implemented even more in transport, which may contribute to reducing some of the current negative phenomena linked to transport (e.g. congestion). Intensive development can also be expected in the field of virtual mobility, where the primary issue is the acceptance of these solutions by their future (potential) users. Technological development thus introduces a high degree of uncertainty into the outlook for future transport developments, since speculating today on the technologies commonly used in 30 years' time is difficult, if not impossible (cf. also the previous discussion on visions published several decades ago).

Other issues with the potential to modify the ongoing transport development in a different or alternative direction represent a broad and internally very differentiated group, which includes both the factors and aspects discussed earlier in this chapter (demographic dynamics and changes in the population structure, energy and environmental aspects, economic aspects, financial aspects) and

other facts not yet mentioned. The impact of these factors can range from local to global and can modify transport development more or less significantly.
On the basis of the combined effect of the listed groups of factors, or the determination axes, we identify the following scenarios of future transport development in the following text:

- the *business-as-usual scenario* represents a continuation of the existing trends in the development of the transport market, which is not significantly modified by regulatory interventions, nor will it be affected by the advent of major technological innovations in the future;

- The *futuristic transport system development scenario* is primarily based on the assumption of successful implementation of major technological innovations that will fundamentally transform existing transport, even without the need for strict and complex regulatory interventions by the public sphere;

- the *scenario of transport market regulation* assumes a massive impact on the transport system in the coming decades due to the introduction of regulations of various nature, in which, given the territorial anchorage of this study, a large influence is attributed mainly to regulations planned in the European Union area (implementation of the current *Strategy for Sustainable and Intelligent Mobility - Directing European Transport into the Future* and other partial strategic and conceptual documents), The Czech Republic (especially the recently approved *Transport Policy of the Czech Republic for the period 2021-2027 with a view to 2050*) and also the City of Brno (especially the comprehensive *Mobility Plan of the City of Brno*). In this scenario, a number of major transport innovations are expected to be implemented, which are often a necessary condition for the successful implementation of the planned regulations;

- the *scenario of realistic development of the transport system* represents the intersection of the key tendencies presented in all previous scenarios; in other words, the scenario takes into account the supporting trends, the projection of which would mean that even through relatively minor partial changes, significant modifications of the transport market organisation can be achieved.

In addition to the above scenarios, some other issues with the potential to modify the ongoing traffic development in a different direction will be briefly described below. In our opinion, these do not have the potential to influence the overall layout of the transport system, so they do not constitute a separate scenario in the concept of this study, which would correspond in its complex nature to the four defined above, but they are nevertheless facts that should not be omitted here in the interests of a fair outlook for future transport development.

5.3.2 Business-as-usual scenario

The basic characteristic of this scenario is based on the assumption that current trends in the transport market will continue. These will not be significantly modified either by regulatory interventions or by the advent of major technological innovations. The broader social and economic context in which passenger and freight transport operates will also not undergo major changes, so that the drivers of transport performance growth operating today (e.g. residential and commercial suburbanisation, the spatial structure of the economy influenced by globalisation processes, etc.) will continue to operate in the future. The *business-as-usual scenario is* thus essentially a kind of reference framework for where the development of the transport system would go and what it would lead to if no major social, economic, political or technological changes were to occur in the next period.

In a *business-as-usual scenario*, we therefore expect that uninterrupted growth in mobility will continue in the coming decades of the first half of the 21st century and therefore demand for passenger and freight transport will continue to rise. This demand will continue to be met by the modes of transport that are already strongly represented in the transport market today, with the fastest growth in passenger transport by road and air, and in freight transport by truck and sea. The key role of these transport modes will of course be complemented, as today, by other modes with relative comparative advantages within specific transport segments, but their share of modal split/share of transport work will not increase significantly. Mobility needs in the passenger transport segment will thus be partly met by the performance of various forms of public transport (public transport and also bus and rail transport) as well as by non-motorised modes (bicycle, walking); a similar situation will prevail in the freight transport segment (partial role of rail, inland waterway, air and pipeline transport). The role of new modes of freight transport (drones, autonomous vehicles, etc.) will be marginal and development will be slow, as it will face technological, regulatory and social barriers. There will thus be no major restructuring of the transport market - over time, of course, we foresee a deepening of the trends already underway, but these will not lead to major modifications of the transport and mobility system as a whole. In line with the thesis presented, we foresee partial changes in the following areas, for example: a slight shift away from car ownership towards car sharing (a greater spread of carsharing and carpooling, especially in urban areas), the development of autonomous vehicle technology, a partial transformation of vehicle propulsion technologies (a greater spread of electric and hybrid vehicles, especially in the segment of shorter, repeated commuting journeys), a greater spread of telematics and traffic flow management and coordination systems, a continuation of the process of the second intermodal revolution, and so on. The demand for the availability of a flexible and private form of mobility embodied by the current form of car transport, which is quite significant for the current transport market, will not be replaced by any other transport solution in the coming decades. The current approach, based largely on a liberal and deregulated attitude towards the transport sector, coupled with efforts to add the necessary additional infrastructure and capacity, will thus continue to be the primary solution applied by the public sector to transport. Partial regulation of the transport sector will of course continue to take place, the tradition of transport policies will not be broken, but the impact of these documents on actual changes in transport behaviour will remain limited.

As a result, the scenario envisages a deepening of the problematic consequences already attributed to transport today. In addition to the worsening problems associated with intensive traffic on the roads (congestion, parking, noise, accidents, etc.), the negative environmental and social impacts of traffic

must also be highlighted. Traffic will thus continue to exacerbate existing social and gender inequalities in terms of limited access to employment, shopping, social and other opportunities for differently disadvantaged people.

If the development of the transport market in the period up to 2050 follows the *business-as-usual scenario*, we assume the following for the South Moravian Region and Brno:

- Congestion of local road infrastructure by intensive passenger and freight traffic. This will put pressure on the construction of other hierarchically superior roads, both in the area of the Brno metropolitan region (completion of the large urban ring road and also the construction of other tangents and outer ring roads allowing to avoid increasingly congested roads in centrally located parts of the metropolis), as well as in the remaining area of the South Moravian Region (completion of the network of motorway links in the direction of all existing major traffic routes).

- Only the slow progress in building the infrastructure needed to develop transport alternatives in passenger and freight transport (e.g. high-speed rail for longer distance transport or the North-South rail diameter as the backbone of urban and suburban transport in the metropolitan region. At the same time, the construction of HSR would allow the existing infrastructure to be freed up for rail freight).

- The metropolitan region of Brno will continue to be increasingly burdened by deliveries from delivery companies, and competition from couriers on bicycles, scooters and electric scooters will remain low after the initial boom, mainly due to the lack of extensive and safe infrastructure for this type of service (cycle paths, dedicated road lanes). Robodelivery will prove to be a capital-intensive and relatively low-use technology, applicable only in the centres of large cities.

- The technology of development of alternative drives for cars and trucks will go forward only very slowly and will not allow significant regulation of the entry of conventional cars and vans into the central areas of Brno and other larger cities in the South Moravian Region.

- The position of Brno and its metropolitan region, both within the settlement system of the Czech Republic and the wider settlement system of (Central) Europe, will not change significantly. Of course, Brno will remain a strong interregional centre, but its importance will not increase in a globalised economy.

- In the period under review, the importance of Brno-Tuřany Airport will increase slightly in line with the continuing process of spatial decentralisation of air transport supply. In addition to a larger number of low-cost airlines, the airport will be integrated into the network of several traditional network airlines through connecting routes. The accessibility of Brno by this mode of transport will thus be slightly improved - the role of air transport will still be significant due to the unfinished construction of the high-speed railway lines.

- The migration of people to suburban communities adjacent to the core city of Brno will continue, resulting in its spatial growth associated with declining population density in the

metropolitan region. Commuting will increase the pressure on the existing and slowly being completed infrastructure, both for individual car and public transport. The gradually developing homeoffice and digitalisation of services will be a partial counter-pressure. Suburbanisation coupled with some home office development will increase the need for local freight transport by NA-N1 vehicles, especially in the context of the gradual growth of e-commerce and home-delivery.

- The negative impacts of transport (congestion, noise, environmental and wider social consequences) will be intensively manifested both in Brno and in the territory of the South Moravian Region. The consequence will be a deterioration in the quality of life, especially in localities immediately adjacent to major traffic routes and in congestion-prone areas.

5.3.3 Futuristic transport system development scenario

The basic features of this scenario are primarily based on the assumption of the successful introduction of major technological innovations that will fundamentally transform existing transport, even without the need for heavy regulatory intervention from the public sphere. This scenario reflects the technological trends discussed in detail in the relevant passages of this study. While the more pessimistic *business-as-usual scenario is* based on an evolutionary approach to transport development, this scenario, on the other hand, represents an optimistic forecast that corresponds more to a revolutionary development.

In this scenario, we assume that relatively fundamental changes in mobility behaviour will be determined not only by technology but also by broader societal changes and the demographic and generational changes currently underway. For Generations Y (millennials) and Z (children of the new millennium), whose members have already been born, raised and grown up in natural harmony with virtual and globalised environments, In fact, compared to their parents' older generations, a modification of value systems will be characteristic, which will also significantly affect transport and mobility behaviour (less pressure to own mobility devices, more emphasis on environmental values, the habit of using information and communication technologies routinely and fully, even as a substitute for physical mobility). Moreover, the relationship to virtual technologies will naturally be reinforced by the current pandemic experience among other social classes and demographic cohorts, so that in the coming decades we can expect a decline in the need for face-to-face contact to deal with everyday life issues, including work and school responsibilities, and probably also a certain decline in routine, regular physical mobility driven by these needs (decline in the importance of the traditional form of commuting).

The construction of high-speed rail is clearly one of the key transport-technological innovations that will be fully implemented in the Czech Republic and Central Europe by 2050. This will lead to the development of theBrno will be connected by direct routes with Prague, Ostrava and Vienna and, via these cities, with other (Central) European high-speed lines leading to other destinations (Katowice, Warsaw, Dresden, Berlin, Munich, Frankfurt, etc.). In an optimistic scenario, we expect at least some of these lines to be in operation sometime in the 2030s. Due to the relatively small size of the South Moravian Region, it can be assumed that the high-speed railway will only fully serve the city of Brno and possibly also the terminal in Breclav, due to its location at the crossroads of lines heading from here to both Vienna and Bratislava. In particular, the regional city of Brno will thus be fully integrated into the Central European and pan-European high-speed train network. In the discussed time horizon up to 2050, it is also possible to consider the possibility that new railway infrastructure constructions could, in addition to conventional high-speed rail, also use magnetic levitation technology (*maglev*) or lines in vacuum tubes (*hyperloop*).

In addition to the high-speed rail transport system, the South Moravian Region will also see further development of related public urban and regional transport systems, which will enable the distribution of the positive effects of the improved transport location of Brno to other areas of the metropolitan region and the entire South Moravian Region. However, in addition to conventional public transport, based, among other things, on the completed regional spine formed by the North-South rail diameter, other modes of transport will also be used in this system. Carsharing and carpooling will have a significant presence on the transport market. The development of these transport concepts will be

stimulated both by restrictions on the private form of individual motoring (e.g. complete coverage of Brno and other towns in the South Moravian Region with parking zones) and by the change in the value system of the incoming generation discussed above, which will consider the use of shared means of transport as a standard way of saturating mobility needs. However, the concept of sharing will not be limited to cars, but will also use other technologically rapidly developing transport alternatives related primarily to electromobility and micromobility - i.e. means of transport such as electric bicycles, electric scooters or electric pedestrians.

The future shape of transport will also be significantly influenced by technological developments in the form of automation. Autonomous vehicles, both in the form of private cars and public transport, will be widely used in the transport market over the next decades. This change will lead to the development of a new type of transport service - *mobility-as-a-service* passenger transport. This way of providing transport to the public will be strongly supported by the public sector, which sees the potential to complement and transform conventional public transport. The expansion of these so-called *smart* solutions will, among other things, make the public transport capacity on offer more responsive to the fluctuating demand for public transport, both within the day and the week, as well as other types of time periods. Automated means of transport and new online or virtual tools will enable the inhabitants of Brno and the South Moravian Region to have fast and convenient door-to-door transport to work and school, as well as for other everyday needs. Providing mobility needs in the above described shared way, or through *mobility-as-a-service* services, will lead to a reduction in the intensity of individual car transport.

The entire transport system will also be efficiently and effectively coordinated and managed by advanced IT solutions that will enable the management of both individual vehicles and entire traffic flows through the application of telematics and navigation tools. As a result, congestion will gradually become an unknown phenomenon in the transport system. Automation will also be fully implemented in rail traffic management, with the introduction of ECTS and more advanced automatic train control systems. These changes will have a positive impact on line capacity and also on rail safety.

Most transport vehicles in 2050 will be powered by fuels other than those based on fossil fuels. Major advances in the development of electro-mobility, fuel cells and some other forms of propulsion will lead to the overall decarbonisation of transport.

The shape of the transport market in the coming decades of the 21st century will also be strongly influenced by the spread and mass acceptance of forms of virtual mobility. Developments in technology will enable the increased use of home-office and home-schooling, leading to a reduction in the number of regularly repeated routine journeys such as commuting to work or school.

In addition to the facts discussed above, there will be the development of a new mode of individual mobility within the region through *air/flying-taxi* or individual or shared air transport adapted to urban or regional conditions through *eVTOL vehicles*, etc. However, this mode of personal transport will continue to be aimed only at the smaller and more affluent section of society for whom it will be affordable. In the context of the newly introduced technological possibilities and new means of transport within the air transport mode, it can be mentioned that the use of suborbital flights for long-distance passenger transport over very long distances can also be expected to develop. In 2050, however, this mode of transport will still be limited to higher-order cities capable of generating

sufficient demand; in Central Europe, this is likely to be limited to Berlin, Munich and Frankfurt, and perhaps, with a higher degree of optimism, to Vienna.
The current form of B2C (business-to-customer) freight transport will completely disappear from the city. The position of parcel services, couriers and other delivery services will largely be replaced by autonomous delivery methods. Drones, delivery robots and autonomous (private) cars, or autonomous mobile and fixed delivery boxes will have their irreplaceable place. A significant part of the delivery will be moved from roads to pavements and into the air. This transformation will require a noticeable modification of existing ground infrastructure - dedicated lanes for different types of transport (robots, small delivery vehicles with lower operating speeds, etc.). This will leave only B2B (business-to-business) freight transport and transport to local micro-hubs within the city. The more freight traffic within the wider city centre declines, the more pressure will be placed on peripherally located logistics centres to serve as a source of delivery not only within the city but also to much of the rest of the county. This trend may be countered by a general trend towards reduced consumption, the increasing popularity of local products and a growing awareness of the need for sustainable behaviour. However, with the development of green sources of electricity, modern modes of transport will be environmentally friendly and thus their use will not be burdened by either environmental concerns or potential regulation. In this scenario, we therefore expect to see an increase in the importance of backbone traction and a reduction in road congestion within urban freight transport.

In this scenario it is necessary to consider two different options for the development of Brno as a regional centre:

- The first one is an optimistic variant, which assumes the gradual development of Brno as an important Central European metropolis, which will be an attractive urban area with a growing population, a higher representation of progressive tertiary and a growing economy. The clear improvement of Brno's transport accessibility on a pan-European scale, coupled with its better connection to the European metropolitan core (the Blue Banana area) via high-speed rail, will represent a significant impetus to its rise within global settlement hierarchies, for example in the ranking of so-called *world cities*. However, Brno's rise may take place at the expense of the surrounding or peripheral rural areas of the South Moravian Region, which will gradually transform from traditional Moravian countryside into recreational natural areas. All of this will contribute to placing significant demands on the development of urban transport itself, especially in the central parts of the metropolitan area, including the construction and operation of the North-South rail diameter, which will gradually be extended to include other directions or arms. Conversely, regional transport from the more remote parts of the region will tend to be in decline on weekdays, while there will be a significant increase in demand for transport at weekends specifically for recreational opportunities. Thus, there will be increasing temporal volatility in regional traffic with respect to weekday and non-weekday travel. Conversely, on weekdays, home-office, home-schooling and other virtual services will somewhat reduce peak-hour traffic and distribute transport demand more evenly throughout the day, allowing for more efficient frequency and capacity planning on public transport. In terms of freight transport, population growth and the development of new modes of transport will create increasing pressure to upgrade transport infrastructure to serve not only growing traffic volumes but also changing transport modes, with this pressure being greatest in an era of natural infrastructure sharing by autonomous and traditional vehicles. The transitive period will require dedicated lanes and the greatest possible separation of these modes. Personal

mobility will further complicate the situation. With the development of freight transport via drones, there will also be a need to build local heliports for drones, which naturally claim space near existing and newly established logistics parks.

- In the latter case, technological development will also take place, but Brno's relative position within the (Central) European settlement system will not be positively affected. The overall improvement of high-speed transport options will allow easier travel to major metropolises, not only within the Czech Republic (i.e. to Prague), but also abroad (i.e. to Vienna or towards German metropolises), which, together with the increasingly intensive use of home-office, home-schooling or online retail and the development of virtual mobility, will lead to a stagnation of Brno's regional importance. This will not keep up with the growth rate of the surrounding more attractive metropolises, such as Prague or Vienna. As a result, the frequency of long-distance travel for the purpose of irregular commuting to more attractive metropolises with more attractive job offers will increase significantly, and the population, educational and economic potential of Brno will actually be siphoned off in favour of the surrounding stronger centres (pump-priming effect). The result will be both stagnation of the service sector and (high-status) job opportunities in Brno. There will not be as much pressure on the suburbanisation processes caused by the attractiveness of the metropolitan centre as in the previous cases, as the inhabitants will, thanks to the above-mentioned development of automated services in regional transport, rather demand housing in other parts of the region, including the peripheral ones, which will allow them very good accessibility to recreational natural locations and, in combination with virtualisation, the possibility to perform their work in these sometimes more remote locations. For freight transport, the pessimistic scenario of futuristic development means more or less the same development as in the case of the optimistic scenario, only with a lower intensity, which will be due to lower population growth in the area of Brno and consequently the South Moravian Region. The actual mode of transport of goods and infrastructure needs will not be avoided in this scenario either.

5.3.4 Transport market regulation scenario

This scenario corresponds with the above-mentioned documents summarising the principles of the currently valid European, Czech and local transport policy (*Strategy for Sustainable and Intelligent Mobility - Directing European Transport into the Future*, *Transport Policy of the Czech Republic for the period 2021-2027 with a view to 2050* and *Mobility Plan of the City of Brno*) and also corresponds with the selected principles of the futuristic scenario. The basic starting point of the above-mentioned European, Czech and local strategy is a shift from gradual evolutionary development and implementation of environmental innovations in transport to a fundamental and at the same time publicly regulated transformation of the entire transport system. In order to achieve such a fundamental transformation of the transport and mobility sphere and also to implement it in a controlled manner, milestones have been set in all these documents, which correspond to selected innovations in transport. Based on these milestones, the transport market regulation scenario will formulate the possible positions of the South Moravian Region and its metropolitan centre Brno in the process of regulated transformation of the transport system.

The first transformational change will be the achievement of 30 million zero-emission vehicles in operation on the roads in the European Union. To this end, it should be noted that zero-emission means a vehicle that does not emit greenhouse gases (mainly $_{CO2}$) or other pollutants that reduce the overall health of the population, such as nitrogen oxides, dust particles, heavy metals, benzo(a)pyrene and possibly other potential pollutants, during operation (not during production or disposal). Only electric or hydrogen powered vehicles are likely to meet these requirements in the automotive transport sector. In this scenario, a real revolution in the composition of the car transport fleet can therefore be expected in the coming decades. The scale of this projected change can be illustrated by the hitherto de facto negligible transformation that has taken place over the past decade, namely between 2012 and 2019. In this period, the number of electric cars in the EU rose from 100 000 to just under 600 000, and by the end of this period there were only 411 hydrogen-powered vehicles registered in the EU. These figures are very low considering that in 2018, a total of 269.2 million passenger cars were registered in the EU-28. Thus, the lack of interest in electric cars, often despite public subsidy policies, can be a barrier to meeting environmental policy objectives in transport.

This planned revolutionary transformation of the vehicle fleet is also linked to another milestone that already has significant implications for transport policies at regional and metropolitan level - the EU's goal of achieving climate neutrality in cities, to which the transformation of the transport sector is to make a significant contribution. This objective will result in a rather intense pressure to reduce car traffic in urban and metropolitan environments in the coming period. This will be manifested by the gradual introduction of parking zones and, in their wake, low-emission zones (by 2030) and even zero-emission zones (by 2050). These changes will be implemented in the area of the South Moravian Region first in its metropolitan centre, i.e. in the core city of Brno, but over time they will also be introduced in other parts of the Brno metropolitan region and in other urban centres of the South Moravian Region. Thus, in 2050, it will be possible to use de facto only emission-free cars in the territory of the South Moravian Region, i.e. electric cars and cars with hydrogen propulsion. The limit for the spread of electric cars will be, among other things, the availability of electricity for recharging batteries. This is not just about the actual amount of energy that will need to be produced, but also about the ability of the grid to cope with the significant temporal variation in car charging - typically after the morning and especially afternoon rush hours.

Closely related to the goal of achieving climate neutrality in cities will be the massive development of shared transport systems based on the use of emission-free cars (mass application of carsharing schemes) as well as other alternative vehicles (electric scooters, electric bikes, electric scooters, etc.). These forms of mobility provision will replace conventional cars, or a mobility system based on private ownership of the means of transport, even more than in the futuristic scenario of transport system development.

The path to climate neutrality will of course also include the further development of public transport systems, which will necessarily be based on different forms of electrified rail transport suitable for serving spatial links/routes over different distances. In fact, electrified rail transport can form the basis of a public transport system both at the scale of cities and metropolises (urban railways in the form of metro or trams), suburban and regional transport (conventional railways), and for longer-distance journeys on a national or international scale (high-speed railways). The rail transport system will be very efficiently connected with other related transport systems throughout the territory of the South Moravian Region, so that the mobility needs of the Region's inhabitants will be sufficiently met by a combination of conventional public transport and the shared transport schemes discussed above. This system will result in a fully-fledged alternative to the private form of mobility linked to the (emission-free) private car in almost the entire territory of the region - the need to purchase and operate it will be strongly minimised. Car ownership will actually become a complication as a result of the fundamental transformation of public services in the provision of public transport, and this phenomenon, so typical of the contemporary world, will largely disappear.

The set system of public services in public transport will also be designed inclusively, which means that it will offer mobility services accessible to all socially, economically, gender, health or otherwise defined groups. This will ensure respect for the principle of equity in transport and will also ensure equal access for all residents of the South Moravian Region to work, school, service, recreation and all other necessities of life.

The provision of public transport services will also be thoroughly planned and coordinated, both in relation to the existing mobility needs of the population and in relation to other modes of transport used (forms of shared transport, private mobility based on the ownership of emission-free vehicles, walking, cycling, etc.). Public authorities at all levels (municipalities, cities, regions) and public transport coordinators will therefore be involved in the regular preparation and continuous updating of sustainable mobility plans. These will not only be produced by public bodies, but also by the private sector, especially large companies, as well as by many other institutions and organisations that have the potential to generate mobility either for their employees and students or for their clients (e.g. shopping centres, university campuses, industrial zones, etc.). The advantage of the South Moravian Region in this area is its long-term experience in planning and coordination of public transport, which are activities provided in the territory of the Region through the company KORDIS JMK.

Mobility planning will also be closely linked to the strategic and spatial planning process. Within this framework, approaches will be applied which can contribute to the fact that the actual creation of mobility needs will be significantly reduced or in some cases almost eliminated as a result of the application of appropriate urban design concepts. An appropriate and well-designed distribution of residential and other functions in the area will enable the population to meet a significant part of their

needs in the immediate vicinity of their homes, so that there will be no need to travel longer distances. At the same time, the sites will be designed to maximise and facilitate active mobility options such as walking and cycling. These modes of transport also have great potential to contribute to reducing car traffic.

An extreme approach to mobility planning, which could be applied if other measures do not sufficiently achieve zero emissions and reduce car traffic, is to regulate the demand for transport, e.g. in the form of an allocated maximum passenger kilometre limit that each person can use during a given period. However, we assume that this way of regulating transport and mobility behaviour is a solution that would be very difficult to implement and could potentially face public opposition.

For long-distance transport, whether nationally or internationally, high-speed rail will be the most common mode of transport in 2050. This will be related both to the fact that the construction of the necessary infrastructure will be completed at that time (in the South Moravian Region, it is mainly the lines currently referred to as RS1 Prague - Brno - Ostrava and RS2 Brno - Vienna/Bratislava), but also to other related measures. It can be assumed that the annual fee for the use of the motorway network for passenger cars will be significantly increased, and it is very likely that these cars will gradually become subject not only to the annual fee but also to the toll system (with certain concessions only for the above defined emission-free vehicles). This will reinforce the spill-over effect of the demand for high-speed passenger transport from cars. TeHowever, this objective may be limited by the low willingness of passengers to give up travelling by car for a variety of reasons, including e.g. loss of transfer time, longer distance to the train terminal, reluctance to give up a familiar mobility routine, etc.

High-speed rail will also take over a significant proportion of air passengers, especially those flying shorter distances to destinations within Europe. Therefore, in the context of the South Moravian Region, the importance of Brno-Tuřany Airport can be expected to decrease. Intercontinental transport will be provided only from major European airports well integrated into the high-speed rail network, and flights over shorter distances will tend to be cancelled over time. Passenger air transport will thus remain in Brno only in the form of seasonal summer flights to more distant holiday destinations.

Even under the *scenario of transport market regulation,* we expect the digitisation and automation of the transport system to continue. However, this process will not only be used for the purposes described in detail in the *futuristic development scenario* (autonomous vehicles, efficient management of traffic flows and flows, *smart mobility*, *mobility-as-a-service*, application of telematics and navigation, drones and autonomous delivery methods in freight transport, etc.), but also more intensively to monitor compliance with the regulatory measures in place. Thus, the regulations on parking, low-emission and emission-free zones in cities will de facto be impossible to violate, as automatic control systems will be introduced, as well as automatic settlement of penalties and fines. This will be another important aspect that will change the overall set-up of the transport system in the region and in its metropolitan centre in Brno.

Within the freight transport segment, in addition to all the general tendencies discussed above, we also expect intensive development of intermodal or combined transport in this scenario. The latter is based on the coordination and interconnection of individual modes of freight transport in such a way

that a functional and efficient chain is created in which the individual modes of transport are integrated in the most efficient way. Thanks to the concentration and subsequent deconcentration of transport flows, capacity-intensive modes of transport can be assumed to be involved in the decisive and often longest transport segments; in the case of land transport, it is particularly possible to talk about the use of rail freight transport in this context. In the South Moravian region, several intermodal/combined transport terminals will be operating in 2050, which will ensure the aforementioned concentration or deconcentration of transport flows. The terminals will be hierarchically arranged, we expect that in the vicinity of Brno could a terminal of (Central) European importance. Greater use of rail will be made possible, among other things, by shifting a large part of passenger traffic to HSR and freeing up the relevant capacity of conventional rail for freight transport.

The *scenario of regulation of the transport market* will also have significant impacts both on the Brno metropolitan region itself and on the entire territory of the South Moravian Region. A number of specific territorial projections have already been discussed directly in the text, so at this point it is only necessary to add the resulting effect of this scenario on the position of Brno and the South Moravian Region in the wider (Central) European context. These effects can be seen in a very similar way to the previous *scenario of futuristic development of the transport system*, because here too the primary carrier technology ensuring accessibility of Brno and the region within this area will be high-speed rail. For this reason it is also possible to formulate here:

- as an optimistic variant, which assumes the gradual development of Brno as a major Central European metropolis with a growing population, a higher representation of the progressive tertiary sector and a growing economy and, as a result, as an entity rising within global settlement hierarchies;

- as well as a variant in which the relative position of Brno within the (Central) European settlement system will not be positively affected, because the easy accessibility of more important metropolises may lead to an increasing dependence of Brno on their labour markets (pump effect).

Compared to the previous scenario, however, we assume a much higher probability of the optimistic scenario under the *transport market regulation scenario*. We base this expectation in particular on the belief that the fundamental changes introduced in this scenario, affecting in essence not only the conditions on the transport market itself, but also including a broader transformation of the urban or social framework in which mobility and transport take place, will significantly improve the quality of life and environment in Brno and the South Moravian Region. As a result, the residential and economic attractiveness of the area will increase, and the reasons for leaving Brno or the South Moravian Region, for example because of the unavailability of jobs here, will be clearly weakened. The optimism in this option is based on the assumption that all the EU's transport and environmental targets for 2050 will be met. When the evolution of key parameters diverges from these targets, one can imagine the many negative impacts that regulation would entail. The main one, and by far the most serious, would be a reduction in the mobility of people and goods, with serious impacts on economic performance and ultimately the well-being of the population. In this scenario, however, we work on the assumption that developments will be in line with the visions presented in the EU and Czech transport policies.

Due to increasing regulation, the load on the backbone networks for freight transport in the South Moravian Region will be reduced and there will be no need for major construction innovations. Within

the city of Brno and the centres of the major cities of the South Moravian Region, the construction of infrastructure for new types of transport will become more important - bases for drones, charging stations for electric vehicles (or battery exchange stations), dedicated traffic lanes for autonomous and robotic vehicles and cycle paths for emission-free courier transport.

5.3.5 Realistic transport system development scenario

The scenario of realistic development of the transport system is based on the premise that none of the previous scenarios can be fully realised in a real situation, because all the conditions necessary for real development to go in the direction assumed by the scenario will never be achieved. In other words, there are always risks or factors that will divert the development of the transport sector, or the development of mobility behaviour, in a different direction.

The risks of *the business-as-usual scenario* are therefore mainly the substantial environmental and social consequences of continuing current transport trends. At some stage, these will inevitably exceed the acceptable limit and therefore trigger at least partial adjustments in the public sphere's approach to transport. This is likely to result in a strengthening of the regulatory elements that are rather absent in the scenario as it stands.

The risk of *the futuristic scenario for the development of the transport system* is overconfidence in both the rapid pace of technological change and innovation and the positivity of its impact on the functioning of the transport market. However, innovations may develop more slowly than expected and even their implementation in normal operation may be more complicated and slower than it seems today, for example due to unknown and unpredictable obstacles. User acceptance of new technologies may also be affected by their current mobility and transport habits and possibly their lack of trust in them. Thus, the transformation of the transport market in the dictates of *the futuristic transport system development scenario* may be far from being realised by 2050.

The risk of *the transport market regulation scenario* may be that the scope of the regulations themselves is too large and that it is impossible to think through all the consequences of the planned actions - even intentions motivated by correct, socially accepted and reasonable goals may lead to other, unintended consequences. The willingness of the population to accept all the plans can also be problematic, as this often requires a rather radical change in transport or mobility behaviour. The transition from the private form of (car-)mobility, which is currently dominant and to which people have been accustomed for decades and to which they have adapted their daily mobility routines, to shared mobility or mobility based on the use of public transport requires a truly fundamental change in thinking and behaviour.

The implication of the existence of the risks outlined is therefore the assumption that the actual, real development of the transport system in the coming periods will indeed follow the trajectories outlined in all the scenarios defined above, but not completely, but only to a certain extent. Thus, the resulting transport market arrangement in 2050 will actually be an intersection of the supporting tendencies presented in the previous scenarios, but none of them will materialise to the full extent described in their frameworks. *The realistic transport system scenario* thus assumes that the current transport market arrangement will certainly change gradually over the coming decades, with the extent or speed of change being influenced in particular by the following tendencies:

- A certain degree of inertia in the existing passenger and freight transport market arrangements, including persistent patterns of transport and mobility behaviour of residents, passenger transport users, businesses, hauliers, customers and other freight transport users.

This factor will be a preservative and inhibitor of a more fundamental transformation of the transport system.

- Within the inertia of transport and mobility behaviours, a particularly strong element will be the routine habit of using one's own personal car in everyday mode, i.e. a car available to its owner in an instantaneous way at basically any time and anywhere. This habit is likely to be the biggest obstacle to a significant increase in shared mobility schemes and also to a more massive shift to public transport. Moreover, the car remains, along with one's own home, one of the key material goods that people aspire to own, and through which they acquire or consolidate their adult status.

- Preferences for modes of transport and forms of mobility behaviour will change in the coming periods in connection with demographic and generational change, but the transition to a mode of transport sharing or the common use of virtual technologies instead of physical transport will be slower than the *scenario of futuristic development of the transport system* assumes. Indeed, even the emerging generations (Generations Y, Z and others) will be confronted with the increased mobility demands and requirements associated with this phase of life as they move into adulthood and may reassess the progressiveness of some of their original mobility plans and intentions as a result of this new experience.

- Slower development, implementation and social acceptance of major innovations may slow down the development of transport automation and the introduction of telematics and navigation technologies in transport. In the case of automated autonomous transport, it is also necessary to mention the related need for new legislation related to the rights and responsibilities of users and operators of this system. Slower technological development may also undermine the growth of virtual mobility. There is also the question of the speed of development of alternative vehicle propulsion technologies and the solution of all the associated technical problems (e.g. sufficient electricity production in the energy sector, the existence of a sufficient network of petrol stations, etc.). As a consequence, some downstream services, such as *smart mobility* or *mobility-as-a-service, will also develop* more slowly.

- Also, the construction of high-speed rail infrastructure, which is an important part of the considerations presented in the previous scenarios, may encounter both financial and spatial-planning problems, and by 2050 the lines may not be opened to the extent necessary for its seamless operation on a national and international, i.e. pan-European, scale. This may lead to high-speed rail not being able to realise its full potential as an alternative to long-distance car and air transport.

- In the coming decades, the different modes of transport will certainly become more interconnected in the transport market into coherent and coordinated integrated transport systems (in the case of passenger transport) or intermodal/combined transport systems and logistics chains (in the case of freight transport), but the pace and intensity of this interconnection may lag behind current expectations.

- Delaying technological progress (development and deployment of electromobility and other emission-free alternative fuels) may result in missing some important milestones planned in

the *transport market regulation scenario and thus* postponing them to a later date. Thus, transport market regulation may take place at a lower intensity and its impacts on the transport regime may be less pronounced and less obvious.

- Some regulatory interventions by the public sphere may be more difficult to accept by residents and other actors in the transport market. In particular, any plans to introduce transport demand regulation could be seen as a disproportionate interference with the rights and freedoms of contemporary society.

Therefore, in accordance with the above theses, in the *scenario of a realistic development of the transport system*, we expect that transport in Brno and the South Moravian Region in 2050 will certainly be less dependent on car transport than it is today, new technologies will certainly be integrated within it and new ways of regulation will also be applied. However, due to the complexity of the transport system and its dependence on a large number of underlying factors, it is difficult today to predict more precise and detailed contours of its internal organisation.

Since *the scenario of realistic development of the transport system is* an intersection of the tendencies described in the three previous scenarios, we deliberately refrain from analysing its specific impacts on the territory of the city of Brno and its metropolitan region and also on the area of the South Moravian Region. These are also specified in more detail in the relevant passages of the previous scenarios and here we would only repeat with different accents what is already stated and commented in the text.

5.3.6 Other issues with the potential to modify ongoing traffic developments in a different direction

The aim of this passage is to briefly introduce some other issues/realities that, in our opinion, have the potential to influence the development of the transport system in other, alternative ways. However, the following overview is by no means complete, but should rather be seen as an illustration of the directions in which one can proceed in thinking on the subject:

- The high price/shortage of oil as a primary source of fossil fuel production - this factor may intensify the pressure to decarbonise transport, and could potentially lead to serious problems for the existing economic, political and social system, which is based on large volumes and high intensity of transport and mobility, even over global distances. An extreme consequence of these developments could be the collapse/collapse of existing societies and the reinforcement of tendencies towards autarkic development of settlement and regional systems.

- Low price/surplus of oil as a basic resource for fossil fuel production (as a result of extraction of unconventional oil, e.g. in the form of shale oil) - this factor could represent a strong incentive to continue transport development along the *business-as-usual* scenario.

- Long-term restrictions on mobility, including international mobility, imposed as a result of the current pandemic situation could intensify the pressure to move towards virtual forms of communication. These could relatively quickly become the de facto only form of mobility for these types of journeys and could result in a decrease in the need for the construction of high-speed rail infrastructure as well as a significant decrease in demand for air transport.

- Long-term and severe global economic recession triggered by the current pandemic situation - this factor could lead to a significant decrease in the amount of available public financial resources needed to build and maintain transport infrastructure, to support public transport systems, and to support the investments needed to develop the decarbonisation of the transport system.

- Significant political and economic changes at different scales. There may be changes on a macro scale concerning the replacement of the position of the economic hegemon, which will not maintain relatively positive economic relations with the European Union, which will lead to gradual economic stagnation leading to certain geopolitical difficulties. Similarly, however, there may also be the emergence or renewal of conflicts on a micro-scale, which may take place in the relative proximity of the South Moravian Region (possible reawakening of the Balkan conflicts, etc.).

- Unexpected technological breakthroughs, such as the discovery of teleportation technology, which could revolutionise current transport and mobility practices by enabling instant mobility over any distance.

- The limit of electrification and automation of the fleet in individual or public passenger and freight transport is the availability of all the necessary mineral raw materials (lithium, silicon, etc.). The possible unavailability of only one of the entire portfolio of resources needed will

not only slow down the development of electrification or automation, but also cause the possible total collapse of development plans along these lines. This unavailability may be due to the exhaustion of those resources that are affordable or technologically available, or it may be conditioned by geopolitical reasons, e.g. the control of one key resource by one geopolitical player, which makes access to that resource impossible.

- Of course, the development of advanced navigation systems is dependent on the operation of increasingly advanced satellite systems, which must not only be developed but also brought into the necessary atmospheric layers and gradually renewed. This poses a certain risk, in particular in that the possible use of military technology or even mere dependence on satellite launches to a non-European power could pose a potential problem for the future in securing these systems. A similar risk could, of course, be posed by an unprecedented astronomical event, such as a collision with a dense meteor shower, which would render some of these systems inoperable, etc.

6. CONCLUSION

The aim of the presented study was to formulate visions of the future development and arrangement of passenger and freight transport, both in a general form valid for the Czech Republic and in a more specific form concerning the territory of the city of Brno and the South Moravian Region. The visions are elaborated with a view to 2050 in the form of four alternative scenarios, which differ from each other by different accents within several key groups of factors or determination axes. These are (i) the degree of regulation or deregulation of the transport system, (ii) the extent of expected technological innovation, and (iii) the existence of a broad group of other issues with the potential to modify ongoing developments in a different direction:

- The *business-as-usual scenario* is based on the continuation of existing trends in the transport market, which are not significantly modified either by regulatory interventions or by the advent of major technological innovations;

- The *futuristic transport system development scenario* is based on the assumption of the successful introduction of major technological innovations that will transform the existing transport system without the need for harsh regulatory measures;

- the *transport market regulation scenario* assumes that in the next decades there will be a massive impact on the transport system as a result of the introduction of regulations of different nature, which will also concern different scales of the transport market (regulation in accordance with the current transport policies of the EU, the Czech Republic or the city of Brno);

- The *realistic transport system development scenario* represents the intersection of the key trends presented in all previous scenarios.

Individual scenarios and the partial circumstances of the development of the transport and mobility system discussed in them may lead to different spatial and regional impacts, both at the level of the core metropolitan region of Brno and within the wider territory of the South Moravian Region. Some of these circumstances may rather stimulate the importance and position of Brno and the South Moravian Region, others do not significantly affect these regional aspects, and some others may even slightly reduce the importance of the territory concerned within the (Central) European and global settlement and economic space. However, a significant pitfall is that even the same phenomenon (e.g. the improved transport accessibility of Brno thanks to its inclusion in the European high-speed rail network) can have quite different effects in different circumstances (in this case, it can both increase the residential and economic attractiveness of Brno and drain its resources to the benefit of stronger centres that can make more of the improved transport location). In our opinion, the knowledge of these potential opportunities and possible future risks and the possibility to prepare for them at least partially are among the most important and valuable outcomes of this study.

Given the relatively distant time horizon of the study, 2050, the author team is aware that the visions presented for the future development and organisation of passenger and freight transport are largely speculative. In fact, a number of events of various kinds may take place over the next 30 years which may significantly affect the currently valid assumptions and assumptions underlying the formulation

of the visions. Readers and users of this study will therefore be grateful if they bear in mind that the future, even that presented here in the transport scenarios, is always only hypothetical.

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6. Mobility Plan of the City of Brno.
7. A strategy for sustainable and intelligent mobility - steering European transport into the future.