Conditionings of Regional Railway Transport in Poland on the Example of a Selected Area

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Abstract. The share (modal split) of passenger transports in the railway transport in Europe including Poland, accounts for ~7%. This reflects rather low share of this sector in the passenger transport. Therefore, the transport policy of the European Union aims at increasing the number of train transports considering it to be the most ecological. Due to some typical features of this transport branch it provides transport services over medium and long distances (more than 300 km). In this context a question should be asked: does development of regional railway transport means which travel over distances several dozen kilometres make sense in Poland? The analysis was performed for an administrative region in the central part of Poland. This region is typical in terms of social-economic and macroeconomic development and spatial development. It covers an area of ~18 thousand km² and has ~2.1 mln inhabitants. In order to answer the question, extensive research has been conducted concerning conditionings of the analyzed region in terms of railway transport development, including a survey among the inhabitants and people travelling by car and those using public transport means (including railway transport). The research included both ‘a travel journal’ of the respondents on a typical weekday, and transport means preferences as well as assessment of passenger transport functioning as part of public transport system in the analyzed region of Poland. Major analyses of transport demand prognoses are based on simulation analyses results for which transport models were used, constructed for three social-development scenarios: optimistic, stabilization and pessimistic. The results of analyses showed that current conditionings are not beneficial for the development of regional railway passenger transports. It is caused by many factors, including: relatively small access to railway transport, small population density, constant drop in the number of inhabitants, aging of the society, very small occupancy of this transport means, very low predicted values of passenger currents, rising costs of these transport maintenance, small interest of inhabitants in the development of this transport system with simultaneous preference for travel by car. The results of analyses showed that regional railway transport system in Poland are uncompetitive as compared to regional bus transport system which are characterized by better availability and flexibility of connections, shorter time of travel, 10-times lower maintenance costs and smaller harmfulness to the environment (taking into consideration that regional railway transports uses mainly diesel locomotives as they are cheaper to run as compared to electrical tractions; whereas in regional bus transports more and more often new, ecological transport means which meet ecological norms of cleanliness of exhaust fumes).

1. Introduction

Passenger transport in the broad sense of the word has been continuously evaluated for years [1], mainly due to an increasing mobility of population and technological development of the means of transport. A significant diversification is also observed in the structure of the choice of the travel mode in different
regions of the world. Invariably however, the car has maintained the biggest share in the modal division of the means of transport, whether used by the driver or passengers. The share of the other travel modes in such a division mainly depends on their accessibility in the given country. For example, rail transport in US passenger traffic accounts for just about 1% of the total transport performance, whereas in 28 European Union member states it is about 7% (most of the regional rail transport takes place in France, Germany and the UK) [1, 2].

The above-mentioned data indicates how difficult it is to develop the public rail transport sector. The impediments include here – first of all – a substantially lower density of railway networks as compared with road networks, and therefore a much lower accessibility of this means of transport. As a result, rail transport is defined by its role as mass transportation used to move people at medium to long distances. Having this in mind, European policies seek to increase the share of rail services in medium (up to about 300 km) and long distance (interregional and international) passenger traffic [3, 4]. Railways are also expected to link the other public and private transport systems comprising multimodal journeys.

In Poland, the share of passenger rail transport is on par with the European average (~7%) [1]. However, the rail transport performance is less than half of the bus and coach transport performance. The popularity of rail services with regional populations is different for different analysed areas, called ‘voivodeships’ (a level 2 region according to the NUTS - Nomenclature of Territorial Units for Statistics). In recent years [5,6], since 2010 there has only been an increase in the total number of rail passengers in three voivodeships. In three other voivodeships the number of passengers carried by rail has remained stable, whereas in the other ten a distinct drop in the rail transport performance has been observed. There is a correlation between the passenger rail transport volume and key factors conditioning the development of public transportation. The voivodeships where an increase or stabilisation of the number of rail passengers is observed have the highest population density in Poland, their migration balance is positive, their employment rates are the highest, their mean monthly salary figures are the highest and so is the density of the regional transport networks, including railways [7].

The travel behaviour trends among Polish, European and global populations have recently shown that the car is still the principal means of transport. Depending on the level of motorisation of a country, the most common side effect of this predominance is that the number of journeys or trips undertaken by means of public transport has more or less decreased [1, 6]. Only in the countries where this transport system is promoted with a greater determination an increase in its share in passenger traffic is noticeable (including for example in some EU countries [1]). In order to make an optimal development plan for this transport sector in a given region, including railways, it is necessary to obtain knowledge of the current and predicted conditions, relevant for the demand for this transport system, and find out about travel preferences of the region’s population.

This article is an attempt to analyse the possibilities of development of regional passenger transport by rail of a selected area of Poland. The analysed area is the Kujawsko-Pomorskie voivodeship, located in Central Poland. The voivodeship, in terms of its social, macroeconomic and spatial development is a typical region, unexceptional in comparison with other Polish regions.

2. Research methodology

As part of a transport study [8], the authors analysed the current state of overall social and economic conditions of the Kujawsko-Pomorskie voivodeship, including its transport infrastructure and the demand for public transport, including passenger rail transport. Projected changes in the spatial development of the analysed area were also investigated. Surveys were conducted to find out about the travel behaviour of the voivodeship residents (using the so-called ‘weekday journey log’), their opinion on the existing transport systems and preferences regarding the choice of travel mode. The surveys consisted in personal interviews. More than 10,000 interviews were held. Furthermore, surveys were
conducted among the users of public transport systems. The results of most of the studies and surveys were used for the development of transport models for the voivodeship, representing the existing situation and forecasts, in order to evaluate the functioning of the public transport in the years to come.

Due to the complexity and randomness of a transport process, as well as to the interdependence of the choice of mode and the current traffic load on individual transport networks, a proper reproduction of the phenomenon requires a great quantity of data describing both the demand (transport needs) and the supply (available transport options) of transport. Therefore, simulation transport models had to be developed to reproduce transport processes within the analysed area, taking into account the transport demand and supply, as well as their mutual dependence. The model was developed in the software environment of Visum provided by PTV Vision, Karlsruhe (German) [9].

Transport forecasting models were developed for three scenarios of economic development of the country: optimistic, stabilised and regressive. The first one assumed that all investments in road, rail and public transport infrastructure planned by the state government and the local government of the voivodeship would be successfully completed, and the mobility and motorisation of the residents would increase. In the stabilised scenario, both the assumed rate and extent of investments were reduced and reflected the current trends in economy, residents’ mobility and motorisation rate. The worst-case scenario, assuming an economic downturn, the rate of implementation of transport investments was the slowest while the motorisation and mobility rates were considered as stable.

3. Primary conditions for the development of rail transport in the analysed area

The Kujawsko-Pomorskie voivodeship covers approx. 18,000 km² and has a population of about 2.1 million, however the number of residents has been steadily shrinking for a few years now. The majority of residents live in cities and towns (more than 60%). The population forecasts for the voivodeship are rather unfavourable, as the number of people living in the area might decrease by as much as about 7% before 2035. Drops in population figures will mainly occur in the cities and largest towns of the voivodeship, most of them as a result of urban sprawl – residents moving out to the neighbouring areas. A steady growth in the share of the oldest age group of the population (>60 y.o.) is also projected to coincide with a decline in the share of the other age groups. Thus, the voivodeship will follow a typical population ageing model. The highest population density is found in the largest urban areas of the voivodeship, however it does not exceed 2,000 people per km² (except for a few municipalities and Inowroclaw which have slightly higher population density figures). Most of the municipalities and communes in the area have a low population density, not exceeding 50 people per km². This has a rather negative influence on the passenger transport potential (demand for public transport services) [7].

Voivodeship development policy documents indicate that until 2025 no substantial changes should be expected as regards the functions and spatial distribution of workplaces and other travel origins and destinations. The key labour markets and residential clusters will be still found in Bydgoszcz, Toruń and their suburbs.

In rail transport, supply means the accessibility of a system of railway lines (including the distribution of passenger facilities). The rail network density in the Kujawsko-Pomorskie voivodeship is approx. 6.7 km per km². The regional railway lines connect mainly the major urban centres of the voivodeship and the main centres of the neighbouring voivodeships (and the country’s major cities in interregional services). The condition of the railway infrastructure in the voivodeship has improved in recent years thanks to investments co-financed by the state and the European Union, however the technical condition of the nodal infrastructure within the railway network raises some concerns. According to a recent report [5], the overall state of the railway infrastructure in the voivodeship is good or acceptable in 88% and inadequate in 12% of the cases. The railway rolling stock, despite systematic upgrades, has a relatively long mean operational life.
In 2016, about 7.8 million passengers used regional rail services in the voivodeship, 80% of whom used regional or suburban services, and the rest took long-distance journeys [5]. The daily passenger flows in the regional rail passenger traffic are shown in Fig. 1. The greatest values of daily passenger flows were observed in the traffic corridor linking the capital of Poland (Warsaw) with a large port city (Gdańsk) via three main cities of the Kujawsko-Pomorskie voivodeship: Włocławek, Toruń, Bydgoszcz, and the largest numbers of passengers were recorded between the three cities. In the other cases, the daily values of passenger flow averaged at 1,000 passengers, and on some routes the flows did not exceed 100.

![Figure 1](image.png)

**Figure 1.** Daily values of passenger flows in the regional rail transport network in the Kujawsko-Pomorskie voivodeship [8]

The capacity utilisation of the available transportation infrastructure is an important criterion of the efficiency of the passenger transport. An analysis of the capacity utilisation rate in the railway traffic in the Kujawsko-Pomorskie voivodeship [8] revealed that it was below 20% (including cross-regional traffic), and reached a maximum of 45% on the trunk lines within the voivodeship.

In the years 2010-2016, a steady decrease in the number of passengers using rail transport was observed [5]. Therefore, there was a clear increase in subsidies for the regional passenger rail transport (see Figures 2 and 3). The downward trends in the average number of passengers per train, shown in Fig. 3, indicates that regional passenger rail services become less and less profitable in the Kujawsko-Pomorskie voivodeship, and justifies the steep increase in subsidies per train-km. The profitability was less than 25% which is approx. 80% lower than the profitability of regional coach services. In 2016, the subsidies for regional rail passenger transport reached nearly €23.2 m, whereas the total expenditure on the operation of passenger rail transport amounted to about €27.8 m (approx. 15% of the total budgetary expenditure of the local government of the Kujawsko-Pomorskie voivodeship). It should be noted that not even 1% of the voivodeship residents used the services, which exposes the poor efficiency of public spending.
Figure 2. Year-on-year changes in the operating performance of the regional passenger railways and in the rail transport subsidies [8, 10]

Figure 3. Year-on-year changes in the unit value of subsidies on passenger rail transport and in the average number of passengers per 1 train [8, 10]

In 2012, the estimated average cost of carriage of one passenger along a distance of 1 km was about €0.14, which is at least twice as much as in the case of public bus or coach transport. The average distance travelled by rail was 35 km.
The results of the surveys of the voivodeship residents’ travel behaviours indicated a very small percentage of utilisation of public transports among them. The regional residents mainly used cars – about 51.5% as drivers and about 41.2% as passengers. Only about 7.3% use the means of public transport, and that including 2.45% of residents using railway services.

4. Spatial structure of trips and passenger structure in regional rail transport
As demonstrated by the results of surveys carried out among passengers, the spatial structure of trips undertaken by them within the Kujawsko-Pomorskie voivodeship by train comprises the following types:

- Internal trips (regional) – 68%,
- Absorbed trips (visiting the voivodeship) – 9%,
- Generated trips (leaving the voivodeship) – 11%,
- Crossing trips (passengers in transit) – 12%.

These statistics show that the vast majority of train journeys were undertaken within the administrative boundaries of the voivodeship. All the other types, where passengers travel into, out of or through the voivodeship, account for a total of 32%.

From the point of view of the passengers’ professional status, the largest group are employed people (46%), then university or college students (28%), secondary-school students (12%) and the people who are not professionally active (12%). The smallest group of passengers are primary- and junior-secondary school students (2%). The professional status of passengers undertaking internal trips only has a very similar structure: the majority of them are employed (47%). The second largest group is students (43%), of which 24% are university or college students, about 15% - secondary-school students and the remaining 3% - primary and junior-secondary school students. Here, the people who are not professionally active are the smallest social group, accounting for about 10%.

The majority of train passengers are people aged 25-60 (28%), followed by young people aged 16-18 (25%), young adults of 19-24 (22%) and children aged 10-15 (21%). People aged 60 and over are the smallest group of passengers (4%). In terms of physical ability, the disabled account for about 4%, and less than 1% respondents indicated a lack of ability to drive.

The structure of the ownership of means of transport among train passengers is interesting: most of them owned a bicycle (52%), 39% of them had a car and 17% said that they did not have any means of transport. It is noteworthy that almost 60% of the surveyed train passengers admitted they had a driving licence.

As far as the trip motivation is concerned, passengers using railway transport in the Kujawsko-Pomorskie voivodeship most often travel to work (30%) and for private reasons (30%). Travelling to school or university was almost equally frequent (28%). Business trips or shopping accounted for a just 7% and 5% of the reasons, respectively. In the case of internal trips by train, however, the structure of trip motivation was a little different: most people travelled to work (nearly 34%), then to school or university (~31%), and about 25% travelled for private reasons. Travelling on business and for shopping belonged to the least common motivations: about 6% and 4%, respectively.
5. Residents’ preferences regarding the travel mode
In order to learn all about the travel behaviour of the residents of the Kujawsko-Pomorskie voivodeship and identify their possible preferences when choosing the travel mode, results of surveys conducted among residents of the analysed area were used. The surveys included such questions as:

- In what circumstances would you travel by a means of public transport? (asked of drivers), and
- In what circumstances would you travel by a means of private transport (car)? (asked of public transport users).

More than 38% of the drivers responded that they would never switch to public transport, regardless of the circumstances. The others considered the following factors which would encourage them to use public transport: regularity and punctuality (~21%), direct connection (~17%), intermodal tickets (~14%) and an easier accessibility of stations and stops (~10%). A very small percentage of drivers indicated a shorter travel time or distance and a lower cost of travel as the decisive factors (about 3%, 1% and 3%, respectively).

In the case of the passengers using public transport about a fourth of them (~26%) responded that the main reason of their travelling by public transport was that they did not have a driving licence or a car. Almost 12% stated they would never drive. The factors indicated by the respondents as material when considering a change to a means of private transport were: smaller road traffic volumes (~14%), a shorter travel time (~14%), a lower cost of travel (~11%), an improved road safety (~13%) and the availability of parking spaces (~12%). An analysis of the responses from the point of view of the respondents’ professional status showed that people who owned a car found a reduction in the cost of travel the most crucial, whereas for people who did not have a car (except for farmers) it was car ownership and a driving licence. Farmers decided that an improved road safety was the key reason they would consider.

Regarding the future, the respondents indicated that the most important factor for their use of public transport would be a low fare (in almost 70% of the cases), followed by a short travel time (~44%). The passengers did not care much about the condition of the road or railway infrastructure, including the state of stops and stations (only about 6% considered these elements). When choosing the train as the travel mode, the respondents indicated the following factors:

- Low ticket price (~72%),
- Short travel time (~52%),
- Regularity and punctuality (~37%),
- Direct connection and travel safety (~35% each),
- Comfort and ease of travel, and the accessibility of stops (~18% each),
- Unrestricted access to travel information systems for passengers (~16%),
- Good technical condition of the means of transport (~11%),
- Intermodal tickets covering all means of public transport (~7%),
- Good condition of linear and nodal infrastructure (~6% each).

6. Demand for passenger rail transport in the analysed area – simulation analysis results
The goal of the simulation analysis was to determine the demand for regional passenger rail transport. To this end, the data on the existing railway network in a transport model was supplemented with information about any projected investments in the development or upgrade of the linear infrastructure of the public transport. In order to ensure the right quality and appeal to passengers using new rail services, at least 10 pairs of train services were assumed (4 in the morning, 4 in the afternoon, 1 around noon and 1 in the evening). As a result of the simulation analysis the projected numbers of passengers using the specific pairs of services on a weekday were determined. The passenger flows on the new lines did not exceed 1,000 passengers per day, which means that the planned extension of the railway network
would not cause a significant increase in the number of passengers using rail transport and – what is more – would be absolutely unjustified from the point of view of its costs and benefits.

The obtained results of simulations evidently indicate that undertaking investments in the development of the regional railway infrastructure is lacks reasonable grounds, as the expected increase in passenger traffic would be negligible. The resultant increase in demand for passenger rail transport in the voivodeship would not be just insignificant – it would lead to a further decrease in train occupancy figures and an even bigger increase in the unit value of subsidies per train-km. Therefore, any funds earmarked for the development of the railway infrastructure should be used in an alternative way, for example to develop the more prospective, more accessible, flexible and frequent public bus and coach services.

The results of the simulation analysis for the most likely – stabilised – scenario of the social and economic development of the Kujawsko-Pomorskie voivodeship are presented in Fig. 4.

![Figure 4](image_url)

**Figure 4.** Map of daily passenger flows in passenger rail transport in the forecast year 2025 with assumed implementation of all projected investments in the railway network (including interregional traffic) [8]

It should be underlined that – according to the results of analyses available in reference books – considering high costs of the construction of new rail links – investments like these are only justified if the projected growth in the number of passengers is much bigger. Taking that into account, with the costs of the contemplated investments in railways of at least €120.6 m, these should be reviewed if relevant changes in the social and economic conditions occur, leading to an increase in the demand for passenger rail transport.

Furthermore, the development of passenger rail transport in the Kujawsko-Pomorskie voivodeship is essentially and economically unfounded as far as its functional area is concerned. Trains as a means of short-distance public transport, carrying small numbers of passengers, are becoming increasingly
uncompetitive with buses and coaches, which are more environmentally-friendly, much more cost- and resource-efficient. In the analysed voivodeship, the average train travel distance in regional transport is 35 km, whereas the voivodeship area is approx. 150 km in diameter. It should be noted that in the case of short distances travelled and small numbers of passengers, which is what we deal with in the Kujawsko-Pomorskie voivodeship, railway transport is at a disadvantage with regard to public road transport in most aspects. Buses and coaches are more accessible for the residents, may offer more frequencies without extra funding, shorter average travel times (origin-destination) and lower costs per passenger. Moreover, most of the shortcomings of public road transport, if compared with rail transport, are less significant in the specific situation of the Kujawsko-Pomorskie voivodeship, for example: environmental aspects (with a small occupancy rail transport is no more ecological than public road transport), acquisition and operation costs of a means of transport (a railcar is almost 10 times as expensive as a bus and uses 4 times more fuel), passenger-carrying capacity (the potential passenger handling capacity would be wasted given the projected flows), and cost-efficiency or profitability (the cost of a train-km in railway transport in the voivodeship is nearly tenfold higher than the cost of a vehicle-km in bus transport). Unfortunately, the rail transport development policy does not follow the transport policy of the European Union [3], where an increase in the role of railways in passenger (and freight) traffic is expected for medium-to-long distances, i.e. longer than 300 km.

7. Conclusions
The results of our analysis of the transport demand and supply in one of typical regions of Poland demonstrate that in the case of passenger rail transport the conditions for the development of this public transport sector are unfavourable. The reasons for this include the following:

- Limited accessibility of the rail transport network,
- Relatively low population density (about 50 people per km², except for large towns and cities),
- Continuous decline in the number of residents,
- Population ageing (according to the authors’ research, nearly 70% of the passengers are young people aged 25 or less),
- Very small utilisation of public transport systems (about 7.3%) and of train services in particular (about 2.4%) by the residents,
- Very small occupancy on regional passenger services (just about 20% on average) and very low passenger flows (about 1,000 passengers per day in most traffic corridors, but less than 100 in some),
- Rising costs of subsidies for regional passenger rail transport (15% of the voivodeship budget),
- Unfavourable trends as regards the intended changes in the choice of mode, according to surveys conducted among the residents (both drivers and passengers using public transport), which indicate an increasing role of the car as the travel mode.

Considering the assumed transport demand forecasts in the analysed area, including the demand for rail transport and the results of the studies of the residents’ preferences and travel behaviours, no indications were found to support the planned investments in the development of the linear railway infrastructure. Any new investment project concerning an extension of the existing network of rail links for regional passenger rail transport would mean a waste of huge amounts of money on the construction of new infrastructure (linear and auxiliary, including nodal) and on the maintenance of unprofitable regional train services. The authors demonstrated that in a region where there are unfavourable trends for the development of passenger rail transport there are absolutely no reasonable grounds to develop the railway network for the purpose of regional passenger transport. The introduction of all the projected linear investments in the analysed area into the transport model, related both to the construction of new rail links, upgrade and restoration of old ones, and to the redevelopment of existing lines to increase the operating speed, will not bring any material benefits in the form of an increased appeal of the rail transport system for existing and new passengers.
In the case of regional passenger transport, trains are becoming uncompetitive with buses and coaches. Short-distance trips and the unfavourable factors listed in the first conclusion above give an advantage to the public road transport thanks to a better accessibility, the possibility to increase the frequency of services at the current level of funding, shorter mean travel times (from the origin to the destination), lower costs per passenger, 10 times lower costs of operation, increased utilisation of the passenger-carrying capacity, lower environmental impact (this considering that diesel locomotives are mainly used in regional services – being much cheaper to run than EMUs, whereas in passenger road transport environmentally-friendly vehicles, e.g. hybrid or electric, are used more and more).

An idea for the development of regional passenger transport in Poland should focus exclusively on an improvement of the quality of the services, for example through rolling stock upgrades, and of the nodal infrastructure. The quality should be also enhanced through tariff integration with the operators of other passenger transport (bus, coach and rail) services within the voivodeship, including the public transport system of the Bydgoszcz-Toruń metropolitan area, and through the introduction of publicly-accessible state-of-the-art passenger information and a modern ticket and tariff system supporting intermodal services in the region.

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