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MODELING COMMUTER'S SOCIODEMOGRAPHIC CHARACTERISTICS TO PREDICT PUBLIC TRANSPORT USAGE FREQUENCY BY APPLYING SUPERVISED MACHINE LEARNING METHOD

Abstract: Predictive modeling is the key fundamental method to study passengers' behavior in transportation research. One of the limited studied topic is modeling of public transport usage frequency, which can be used to estimate present and future demand and users' trend toward public transport services. The artificial intelligence and machine learning methods are promising to be better substitute to statistical techniques. No doubt, traditionally been used econometrics models are better for causal relationship studies among variables, but they made rigid assumptions and unable to recognize the pattern in data. This paper aims to build a predictive model to solve passengers' classification, and public transport usage frequency using socio-demographic survey data. The supervised machine learning algorithm, K-Nearest Neighbor (KNN) applied to build a predictive model, which is the better machine learning method for dealing with small datasets, because of its ability of having less parameter tuning. Survey data has been used to train and validate the model performance, which is able to predict public transport usage frequency of future users of public transport. This model can practically be used by public transport agencies and relevant government organizations to predict the public transport demand for new commuters before introducing any new transportation projects.
Keywords: machine learning; modeling; public transport; socio-demographic status; Hyderabad

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Introduction

History reveals that in the past, Pakistani cities were characterized by low population, shorter trips length and higher non-motorized transport (Thomson, 1977; Tiwari, 2002; Imran and Low, 2003; Singh, 2005; Imran and Low, 2007). However, these characteristics changed as the spatial structures built with time and that were only accessible by public transport and privately owned vehicles. Therefore, public transport trips share to non-motorized has grown in cities of Pakistan. The expansion of cities has increased the trip lengths for urban residents, which make walking less feasible than before and force residents to shift from non-motorized mobility to motorized mode of transport (Imran, 2009). In these scenarios, public transport including both formal and informal, aims to provide quality services to urban resident's mobility at very lower cost as compare to private mode of transport. Many efforts have been done to improve the public transport system in order to make it more convenient, comfortable and environment friendly (Buehler, Lukacs and Zimmerman, 2015; National Transport Authority, 2016; Transport for London, 2016). However, after these efforts there are many reasons of decline in public transport ridership e.g., higher household income, credit access at low interest rates and low tax ratio, encouraged resident's private vehicle ridership (Bliss, 2017; Levinson, 2017). Urban residents often consider public transport inferior and decline use when their overall household income rises. The dwindling demand aimed at public transport usage is explained by a failure in the quality of service, congested buses and time delays, altogether dishearten residents, push them away from public transport usage and to more reliable replacements i.e., private mode of transport (Orcutt, 2017). Therefore, it is necessary to understand residents' decision making to use public transport in order to learn commuting pattern and public transport perception in the eyes of residents. This helps to ensure that residents continue to use the service of public transport and either existing public transport services attracts new residents (Fujii and Kitamura, 2003; Fellesson and Friman, 2008). Some existing studies have estimated some key effects of public transport service quality based on information collected from users, e.g., (Lei and Mac, 2005; Schiefelbusch and Dienel, 2009; Lai and Chen, 2011; Imaz et al. 2015).

Residents' usage frequency choice of travel mode depends on several socio and demographic factors (Cervero, 2002; Ermagun, Rashidi and Lari, 2015). Being most important deterministic, these factors have been neglected to estimate public transport usage frequency in cities of Pakistan, which ultimately helps to determine public transport demand. Many existing studies are based on historical perspectives and present situations of public transport in cities of Pakistan but to our knowledge very less attentions has been given to deal the future bottlenecks. This study proposed a deeper understanding of residents' attitude towards public transport usage frequency based on socio and demographic factors. An attempt has been made to build a predictive model using K-Nearest Neighbor (KNN), a machine learning algorithm – an advance artificial intelligence approach, which can predict the public transport usage frequency for future coming users of public transport.

The paper has been arranged as follows: section 2 explains the literature review, which comprises the existing studies used statistical techniques, machine learning and artificial intelligence techniques to study public transportation problems by different means of data. The section 3 explains the data used to train and test the predictive model. The section 4 explains the model formulation, section 5 explains the model evaluation and section 6 explains the conclusion of this study and future directions.

1. Literature Review

Public transport plays a vigorous part in shaping city and has always be the reason for sustainable alternative to private mode choice for travel, because of its capacity to reduce traffic congestion and lessen the environment pollution (Tsai et al., 2008). The association between public transport usage frequency and socio-demographic variables has well understood but empirical evidences on this topic is limited. Only few existing studies, e.g., (Badoe and Yendeti, 2007) investigated the public transport usage behavior and studied the factors influencing the ownership of transit pass and daily number of trips by using binary probit model and count variable regression model. Although, this study described well the role of occupation in holding transit pass but had not reveled other socio-demographic variables influencing the usage frequency of public transport (Habib and Hasnine, 2019). In another existing study, e.g., (Farber et al., 2014) a joint model based on econometrics methods was developed to study public transport trip frequency and travel distance by individuals using household survey data. This model incorporated the endogenous relation of trip frequency and travel distance. Among many socio-demographic variables, gender, age, ethnicity, income, occupation, education level and geographical locations of households was found to be significant to study residents' behavior of public transport usage.

Most of the existing studies used statistical models to estimate the passengers' demand of public transport, e.g., (Vicente and Reis, 2018). In some recent decade, researchers and practitioners of public transportation have used different econometrics techniques to solve public transport problems using smart card data, e.g., (Seaborn et al., 2009; Munzinga et al. 2012; Tao et al., 2014, Tao et al., 2016 and Haibo et al., 2016). The other existing studies found which used smart card data to study public transportation problems, e.g., (Agard et al., 2006) studied the public transport users' behavior and trip habits. (Baghai and White, 2005) studied consistency of passengers' travel behavior over time and proposed approaches to retain users. (Utsunomiya et al., 2006) forecasted the demand and proposed approaches to improve user trust and fare adjustment according to needs of users. (Park and Kim, 2008) used historical data to estimate future trends by creating a future demand matrix and (Trépanier and Morency, 2010) model the loyalty of passengers to use public transport. Unfortunately, in developing countries like Pakistan public transport operators and authorities do not open this kind of rich data for research, which is the limitations to use this kind of data for research.

However, most of these studies used regression models to predict demand, which are more suitable for casual relationships studies. These linear models are not able to take into account the out-of-sample observations which ultimately reduced the predictive performance. Due to these reasons, our aim is to increase predictive capabilities using machine learning technique, which are promising to be the better as compared to traditionally been used econometrics models. In the era of artificial intelligence and machine learning, predictive models have attracted many researchers' attentions but usefulness of these techniques are still largely unexplored in studies of public transportation. The purpose of this paper therefore is clearly defined. We used supervised machine learning algorithm, i.e., KNN to form a predictive model of usage frequency of public transport and trained it using survey data related to socio-demographic attributes of residents. During model training process, it learns the pattern that arose. However, after training the model the testing process was started to check how well our model has trained and able to predict new users' usage frequency of public transport.

2. Methodology

The second largest city of Sindh province, Hyderabad, Pakistan (Baig, Rana and Talpur, 2019) was considered as study area for this study. This emerging metropolitan city consists of 1,732,693 citizens, which includes it among the top 10 most populated cities of Pakistan (Government of Pakistan). All types of city's public transport considered under the umbrella of public transportation in present study i.e., buses, mini buses, mini carriages and auto Rickshaws (Government of Sindh, 2019). In order to collect suitable data, online social media based questionnaire survey was conducted by targeting the selected audience. This technique of getting more data in less period of time has been used in many studies, e.g., (Ho, 2015; Talpur et al., 2017). Questionnaire was prepared using Google Forms and link was shared through social media to selected audience. Further, questionnaire was also shared via email to collect the responses. A convenience sampling technique was adopted for questionnaire survey (Ross, 2005). A total of 383 valid responses were collected in return of questionnaire survey.

The study is limited as it includes unequal gender distribution. Males were predominantly participated in survey constituting the 71.8% of total respondents as compare to females which constitutes 28.2%. As, the survey was conducted online, therefore, young people of age 21-30 years were dominant with 78.5% of total respondents. While, 17.5% of respondents belonged to 20 years or below and 4% belonged to 31-40 years' age group. Majority of participants had bachelors or higher degree (73.91%), while the rest had attended high school (2.6%), diploma (1.3%), and college (22.19%). The audience were also predominantly students (73.36%) followed by 18.8% private employees, 3.92% government employees, and 3.92% others (including self-employed and labor). As the audience were predominantly students, therefore, most of the respondent's personal income (51.5%) was less than 10,000 PKR. This may possibly be generated by part time work. Meanwhile, 13.5% of respondent's have monthly income of 11000-20,000PKR, 13% of audience have monthly income of 21000 – 30000 PKR, 10% participants have 31000 - 41000 PKR, and 12% respondents earned more than 40,000 PKR monthly income. The sample is almost equally distributed in respect to car ownership variable as 52.22% of respondents owned a car as compare to rest of 47.78% of respondents. On the other hand, 81.8% of respondents owned a bike, while only 18.2% don't have bike.

Responses related to Public transport usage frequency showed that only 13.6% never used public transport but the rest had experience of traveling public transport. Among the participants, 13.3% said that they use public transport daily, 17.8% use once a week, 28.3% respond in using public transport few days in a month, and 27% respondents told that they used public transport few days in a year.

After getting the data, the modeling approach as shown in **Fig. 1** was applied in order to bring the data, train our model on training data and then validate on testing data to check and evaluate the model performance.

3. The Model

3.1 K-Nearest Neighbor Algorithm

The KNN is a supervised instance-based non-parametric machine learning algorithm which can be used for solving both classification and regression tasks (Hand, Mannila and Smyth, 2001). The KNN belongs to supervised machine learning group of algorithms. Because of this, it always given a labelled dataset consisting of training observations (x, y) and would capture the relationship between x and y. The goal in this is to acquire a function $h: X \rightarrow Y$ so that given an unseen instance x, $h(x)$ can surely predict the corresponding output y.

The KNN works on the concept of majority votes between the k most similar observations to a given unseen observation. The k is the hyper parameter of KNN algorithm which is need to find out during hypermeter tuning of the algorithm (Friedman, Baskett and Shustek, 1975). Similarity in observations is defined according to a distance metric between two data points. A general optimal choice as suggested by many researchers are Euclidean distance which can be calculated using Eq. (1).

$$d(x, x') = \sqrt{\sum_{i=1}^{n} (x_i - x_i')^2} \tag{1}$$

where, x *and* x' are representing Euclidean vectors, starting from initial point and ending at terminal points respectively.

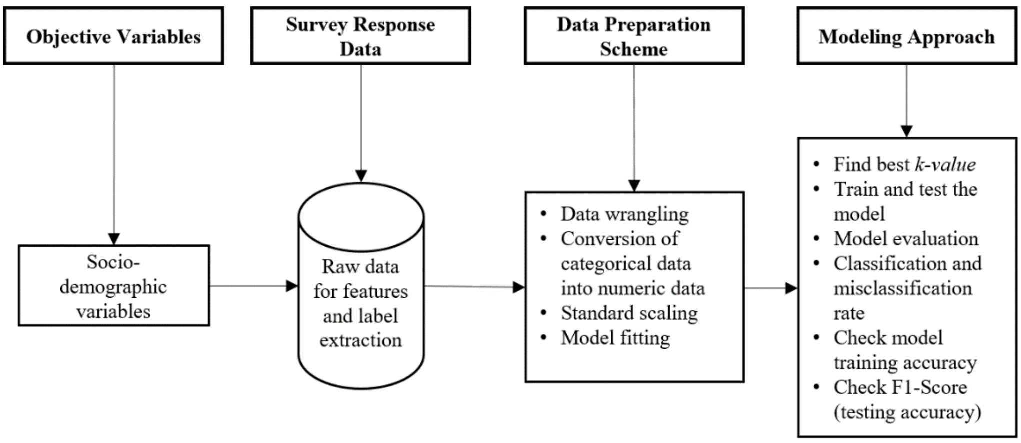

Fig. 1 Modeling approach diagram

Providing numeral k to an invisible instance x and a correspondence metric d, the KNN algorithm runs through the whole dataset for calculating d value between x and every training instance and approximate the conditional probability for each class which can be calculated using Eq. (2). Process diagram for KNN has shown in Fig. 2 indicating the working conceptual method for algorithm.

$$P(y=j\mid X=x)=\frac{1}{k}\sum_{i\in N_k} I(y^i=j) \qquad (2)$$

where, $(y=j\mid X=x)$ is representing the corresponding observations, k is hyper parameter $I(y^i=j)$ is the indicator function evaluates to 1 when the argument x is true and 0 otherwise.

Finding the optimal value of k is important tasks during tuning hyper parameter for the model as it required to get the best performance of the model (Jahangiri and Rakha, 2015). One of the frequently used method to find the k value is k-fold cross validation. The k-fold cross validation is a technique to find the prediction error. Subsequently, it is the finest method to define the model parameters.

3.2 Model Formulation

Meanwhile, machine learning techniques are suggested to be used for data having big observations but there are no any restrictions to use these machine learning techniques for data having less observations (Sug, 2012). One problem that may arise for small data is the overfitting and the outliers but experts have proposed different ways to deal with such issues. First suggestion to that is to select ensemble machine learning technique with minimum hyper parameter to tune, which helps to less in complexity in the model (Maheswari, 2018). Among predictive algorithm, the KNN is one of the best algorithm

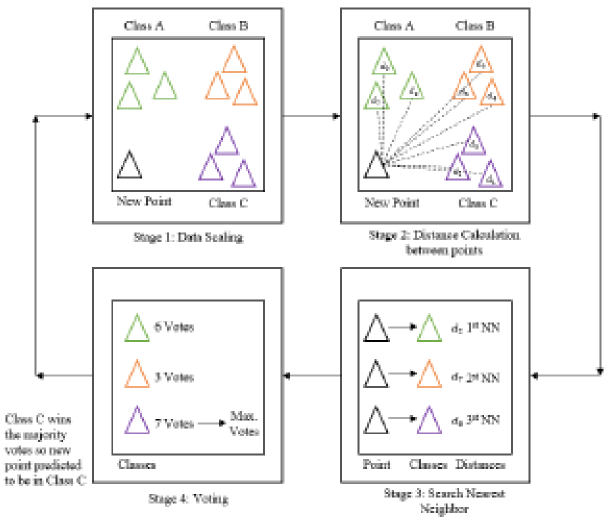

Fig. 2 Conceptual framework of K-Nearest Neigbor Algorithm

to work with small data as this machine learning technique has only one hyper parameter to tune. Second suggestion to small data issue is the increase the training size in order to increase the predictive performance of model (Zhang and Ling, 2018). Data was randomly chosen for training of the model and then validating it using testing data. The 85% observations were selected for training the model and remaining 15% observations were used to validate the model. Analysis has been done using SciKit-Learn library of Python version 3.7 and anaconda framework. The KNN have only one parameter to tune which is number of neighbors named as k value. This number helps in assigning decision boundary to classes. Using k-fold cross validation, in general 5 or 10 folds' cross validation is best for finding optimal value of k (Kohavi et al., 1995; James et al., 2013). The data was examined for different error values as shown in Fig. 3 indicating at 1 neighbors ($k = 1$) have lowest mean error which is not the optimized solution for model because when k-value is very small model shows more blind behavior to overall distribution of classes. On the other hand, for large k value averages extra voters during each prediction and model become more resilient to outliers. It is suggested to choose odd number for k to avoid complexity of class selection so from next error value model at 5 neighbors showing more robustness so $k = 5$ was chosen to train the model.

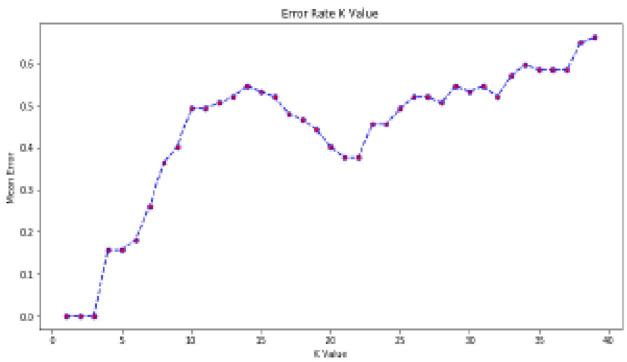

Fig. 3 Mean error value for different k value

4. Model Evaluation

In order to check the predictive performance of model on validation data, confusion matrix (CM) was constructed to estimate the observations of actual and predictive classes. CM is a technique to identify classification and misclassification rate, recall and precision values of the model. The general interpretation of confusion matrix as shown in Eq. (3) can be used to find out recall and precision value.

$$CM=\begin{bmatrix} C_{ij} & \cdots & C_{ij} \\ \vdots & \ddots & \vdots \\ C_{ij} & \cdots & C_{ij} \end{bmatrix} \qquad (3)$$

where, C_{ij} is the class for ith row and jth column of the confusion matrix. In this matrix all the correct predications are present in the diagonal (correctly classified) and the values outside the diagonal is to estimate misclassification (wrongly classified) values. Classification and misclassification rate can further be used to calculate precision value as shown in Eq. (4) and recall value as shown in Eq. (5) of the model. Average of recall values can further be used to estimate the training accuracy of the model.

$$\text{Precision} = \frac{M_i}{\sum_j M_j} \quad (4)$$

where, $\mathrm{M_i}$ is correctly predicted class i and $\sum_j \mathrm{M_j}$ is the sum of both correctly and incorrectly predicted class i.

$$\text{Recall} = \frac{M_i}{\sum_j M_{ij}} \quad (5)$$

where, $\mathrm{M_i}$ is correctly predicted and $\sum_j \mathrm{M_{ij}}$ is sum of out of all the cases, which labeled as *i*.

CF for model as shown in Eq. (6) indicating the classification and misclassification values observed during testing the model. Rows in the matrix shows the predicted classes and columns shows the actual classes observations. For frequency daily (D), 1 observation has been misclassified as frequency few days in a year (FDY). For frequency few days in a year (FDY), 1 observation have been misclassified as frequency daily (D) and 2 observations as frequency never (N). For frequency few days in a month (FDM), 3 observations have been misclassified as frequency few days in a year (FDY), 4 observations have been misclassified as frequency once a week (OW) and 1 observation has been misclassified as frequency never (N). For frequency once a week (OW), 1 observation have been misclassified as few days in a year (FDY) and 2 observations have been misclassified as frequency never (N). For frequency never (N), 1 observation has been misclassified as frequency once a week (OW). By taking average of the recall values it is estimated that overall training accuracy of the model is 72.4% indicating good predictive performance of the model. For testing accuracy of the model, F1-Score as shown in Fig. 4 indicating testing accuracy of frequency daily, few days in a year, few days in a month, once a week and never is 67%, 76%, 81%, 60% and 57% respectively.

$$CM = \begin{bmatrix} KNN & D & FDY & FDM & OW & N \\ D & 2 & 1 & 0 & 0 & 0 \\ FDY & 0 & 11 & 3 & 1 & 0 \\ FDM & 1 & 0 & 19 & 0 & 0 \\ OW & 0 & 0 & 4 & 6 & 1 \\ N & 0 & 2 & 1 & 2 & 4 \end{bmatrix} \quad (6)$$

Conclusion

This research focused on modeling for predicting public transport usage frequency in the city of Sindh province, Hyderabad, Pakistan. For the purpose of predictive modeling, K-Nearest Neighbor supervised machine learning algorithm is used, which is better for modeling based on observations less in size and small dataset. Looking to the historical studies, we realized that, no attention has been given before to study modeling public transport usage frequency applying machine learning techniques. We proposed a robust model using K-Nearest Neighbor algorithm, which is able to predict the residents' interests toward usage of public transport in future. Such studies can help urban transport planners, policies maker and experts to estimate the future demand before introducing any new transport system. Special attentions should be given to public transport demad when forming and evaluating transport policies in cities of Pakistan. Transportation organizations working in cities of Pakistan do not have the excessive big data but census data and micro-level survey data can revival the socio-demographic status of commuters, which can be further used to study transportation problems applying machine learning methods.

These advance modeling approach needs data relatively big in observations. In future, researchers can bring advance data sets, e.g., GPS location data, smart card data, built environment data and social media data to study transportation problems in cities of Pakistan. The study is limited as it used questionnaire based data, which can be improved in future by using big data. Transport organizations can help to provide the data or open it publically for researchers to better and advance modeling of transport which can ultimately help to improve overall transport system.

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THE EFFECTIVENESS OF A REGIONAL RAILWAY LINE - CASE STUDY ON THE TRACK HODONÍN - HOLÍČ NAD MORAVOU

Abstract. The effectiveness of regional railway lines has been a much discussed theme recently mainly in case of lines which are not sufficient per the capacity requirements of carriers, or vice-versa, which are utilised only to a minimum extent. The article deals with the assessment of options how to utilise the railway line Hodonín - Holíč nad Moravou with respect to its inclusion into Revision of Transport Expenses document. Based on the analysis of present operation situation in that border crossing as well as on the analysis of passenger and freight railway transport operation various options of utilising the line have been investigated with respect to operation and economic options of individual alternatives.
Keywords: regional railway transport, effectiveness, passenger transport, freight transport, manager of infrastructure

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Introduction

A regional line is of a local importance; it serves for public railway transport and it runs to a national or another regional line. Transport on such a line is usually characterised with a simplified control and operation of motor wagons, or electric units in passenger transport. In freight transport the fraction on regional lines is provided mostly with handling trains.

The issue of sustainability and operation on regional lines is dealt by Dolinayová et al. (Dolinayová et al., 2017). In their article they point out the importance of regional railway transport in context of an economic growth of regions. Regional railway transport has a non-substitutable place in regions with a higher standard of living, and in case of providing a quality service it leads to a significant improvement of performances (Masek & Kendra, 2013). Gašparík et al. investigated the provision of services in regional passenger railway transport and the interaction of a passenger with an order party of the transport service (Gašparík et al., 2015). An ecological aspect of regional railway and road transport is covered by Skrúcaný at al. (Skrúcaný et al., 2016) who studied the environmental burden caused with road and railway regional transport on the basis of simulating the fuel consumption of a bus and a train on Žilina - Rajec line with a certain amount of passengers. Seidenglanz et al. referred to a diversified organisation of regional public transport in three neighbouring Central European countries: the Czech Republic, Austria and Germany (Seidenglanz et al., 2015). Guihéry considered costs structure of operating regional railway passenger transport before and after competition and showed that the introduction of competition in Leipzig region had reduced the level of subsidy by 20 %, and improved productivity of the incumbent operator (Guihéry, 2014).

Advantages of regional railway transport mostly include a small negative environmental burden. However, there are also railway lines where performances of railway transport drop from year to year and railway transport is replaced with other modes of transport, mostly the road one.

The railway line Hodonín (CZ) - Holíč nad Moravou (SK) is one of such lines. Passenger transport was stopped here in December 2004 and freight transport was stopped here even at the beginning of the 90s in the 20th century, in spite of the electrification (25 kV/50 Hz) which was finished in December 1987. Thus there in the Slovak section this line was listed in Revision of Transport Expenses document, which was prepared by the Ministry of Transport and Construction of the Slovak Republic in order to reduce costs expended on railway lines where railway transport was operated only in small extent or not at all. This document contains more than 25 railway lines in the territory of the Slovak Republic operated by Železnice Slovenskej republiky (ŽSR, in English: Railways of the Slovak Republic).

1. Methodology

A railway line creates a transport route for rail vehicles in order to provide railway transport. The railway infrastructure is built, maintained and operated by the government through ŽSR, a manager of the infrastructure (Ministerstvo dopravy a výstavby SR, 2011).

Whether the operation and maintenance of a railway line is effective or not, and to what extent, is observed using indicators anchored in the Contract for the Operation of Railway Infrastructure. It is a contract between the Ministry of Transport and Construction and ŽSR. The current contract has been concluded for the period 2017 - 2021. Usually it is made for 4 years and it contains rights and duties of both parties, as well as sanctions in case of not fulfilling conditions of the contract. Table 1 lists individual groups of indicators and their corresponding indicators (Železnice Slovenskej republiky, 2016).

Table 1. Indicators of Contract for the Operation of Railway Infrastructure

Group of Indicators	Indicator
Operation	Length of lines in km
	Categorisation of lines
	Number of transport points for passenger and freight transport
	Throughput of line sections
	The highest line speed
	Accidents caused by a manager of infrastructure by categories
Performance-related	Regular scope of train transport
	Utilisation of a forward performance of a line section
	Degree of occupancy of a line section with regular transport
	List of carriers
	Number of employees who guarantee the subject of the Contract for the Operation of Railway Infrastructure
Qualitative	Standards of railway lines and stations
	Fulfilling of a line timetable
	Full overviews of deviations from construction parameters of operated lines
Economic	Summary transport performances of a minimum access package and line access to facilities of passenger and freight transport, as well as to facilities of the carrier
	Proceeds out of the fee for railway infrastructure within the division into passenger and freight transport, and the carrier
	Cost rate
	Performances expressed in train kilometres and gross tonne-kilometres
	Total real revenues and costs per a line section

Individual indicators are observed by a manager of the infrastructure in more detail in the module Controlling within the SAP ECC System. Quarterly a qualitative indicator of a full overview of deviations from construction parameters of operated lines is evaluated. Half-yearly economic indicators of summary transport performances and proceeds out of the fee for railway transport route are evaluated. Other indicators are evaluated annually (Dolinayová & Nedeliaková, 2015).

To verify a forward performance in chapter 4 we will use the methodology of a theoretical forward performance of ŽSR which is characterised with the following steps (Gašparík & Šulko, 2016):

- in the first table there are multiples of number of trains N_1 and N_2 which represent the number of trains,
- in the second table there are times of occupancy of an interstation section with individual sequences of trains,
- total time of occupancy T'_{obs} is calculated as a sum of multiples of a product of the number of trains of a given sequence, and unit time of occupancy of the given sequence, i.e. matching cells of both tables are multiplied,
- value T'_{obs} will be increased in 10 %,
- time of occupancy is calculated as a share of increased time of occupancy and the number of trains,
- average time of occupancy t_{obs} and time of intervals t_{medz} is determined,
- required time of intervals is found per the regulation ŽSR D 24,
- actual time of intervals will be compared with the required one $t_{medz}^{pož} \leq t_{medz}^{sk}$,
- a prospective practical throughput as well as other qualitative indicators of a line timetable will be calculated.

The rate of occupancy is represented with an indicator of the degree of occupancy s_o. The degree of occupancy is a ratio of the total time of occupancy T_{obs} of the investigated operation facility and the total calculation time T (usually 24 hours) which is reduced with the time required for maintenance and repairs $T_{výl}$ and occupancy of permanent handlings $T_{stál}$ (Gašparík & Šulko, 2016).

$$s_o = \frac{T_{obs}}{T-(T_{výl}+T_{stál})} \qquad (1)$$

A line timetable is considered sufficiently occupied when it shows a degree of occupancy from 0.5 to 0.67. The degree of occupancy is a dimensionless number (Gašparík & Šulko, 2016).

2. Operation-Technical Characteristics of the Line Section Hodonín - Holíč nad Moravou

After a dissolution of Czechoslovakia on January 1, 1993 and origin of two sovereign states of the Czech Republic and Slovak Republic the originally domestic line became one of the shortest interstate lines connecting two states.

The railway border crossing Hodonín - Holíč nad Moravou comprises (Železnice Slovenskej republiky, 2018):

a) the frontier transitional station Hodonín,
b) the frontier station Holíč nad Moravou,
c) the frontier line.

2.1. The Frontier Transitional Station Hodonín

RS Hodonín was made available to public on May 1, 1841. Alongside on that date there was an operation on the line Břeclav - Uherské Hradiště initiated.

In 1999 - 2000 RS Hodonín underwent a complete reconstruction including the modernisation of a station interlocking plant and access for disabled passengers. Currently the interlocking plant is controlled from CDP Přerov. Table 2 contains the number and type of tracks located in RS Hodonín (Pagáč, 2018).

Table 2. The Number and Type of Tracks in RS Hodonín

Type of a Station Track	Number

transport	19
handling	22
other	5

There passes the 2nd transit corridor of Správa železničnej dopravnej cesty (SŽDC, in English: Railway Infrastructure Administration) through RS Hodonín. There run 5 active sidings into RS Hodonín.

In RS Hodonín there are the following services available for passengers (České Dráhy, 2018):

- international and domestic ticket office with the option to pay with a card or cash (also in € currency),
- integrated transport system with the option to validate the ticket in a stamping machine,
- bike rental service,
- waiting room,
- toilet for the disabled,
- exchange office operated by the company České Dráhy, a. s. (in English: Czech Railways),
- left-luggage office.

At the same time the RS is equipped with elevators and guide elements for visually handicapped passengers.

RS Hodonín does not provide any equipment (side or front ramp, customs clearance, derrick, etc.) for carriers in freight transport (ČD CARGO, 2017).

2.2. The Frontier Station Holíč nad Moravou

Railway station Holíč nad Moravou was made available to public on October 27, 1891. On that date there was also an operation on the line Hodonín - Holíč nad Moravou initiated.

The rail yard and dispatch shed have not undergone a considerable reconstruction. In RS there is a station interlocking plant of the 1st category activated - group light signals independent on the position of changes with manually reset changes. There in Table 3 is the type and number of tracks in RS Holíč nad Moravou listed (VLAKY.NET, 2004).

Table 3. The Number and Type of Tracks in RS Holíč

Type of a Station Track	Number
transport	8
handling	3
other	2

Through RS Holíč nad Moravou there also passes a line joining Kúty and Skalica in Slovakia. In RS Holíč nad Moravou there between the last and the first train in the line timetable a traffic closure of the transport service is introduced; its duration always changes to the date when the line timetable comes into force.

Passengers can wait in a waiting room, however, in the RS there is no ticket office. Tickets can be purchased via the Internet or another alternative selling channel, or at a conductor on the train (Železničná spoločnosť Slovensko, 2016).

In freight transport there is a side ramp available to carriers; it is located on the track No. 4 and its surface area is 170 m^2. The station is not occupied by an employee of the carrier since handing of shipments in and out is performed during the stay of a handling train (Železničná spoločnosť Cargo Slovakia, 2018).

2.3. The Frontier Line

The interstation section Hodonín - Holíč nad Moravou is a single-track section and it is electrified with an alternate traction supply substation 25 kV/50 Hz (Železnice Slovenskej republiky, 2018). The electric operation began on December 3, 1987. Currently it is used only in case of a route deviation within passenger and freight transport, which happens only to a minimum extent (Tomančák, 2000). Table 4 lists a characteristics of the interstation section as it is introduced by Local convention for carriers in the given border crossing (Železnice Slovenskej republiky, 2018).

Table 4. The Characteristics of the Interstation Section

Position of the state border	km 3.009
Distance from axes of dispatch sheds of neighbouring RSs	6.543 km
Boundary of the frontier line	RS Hodonín - entry signal HS on km 0.990
	RS Holíč nad Moravou - entry signal HS on km 5.900
Stops on the line	Hodonín stop on km 2.100
The highest permissible line speed	60 $km.h^{-1}$
Braking distance	400 m
The biggest length of the train including a railway tractive vehicle	665 m
The biggest admissible weight on axle	22.5 t (Hodonín - km 2.920)
	20.5 t (km 2.920 - Holíč)
The biggest admissible weight on a standard meter of a wagon	8 t/m (Hodonín - km 2.920)
	7.2 t/m (km 2.920 - Holíč)
Line class	D 4 (Hodonín - km 2.920)
	C 3 (km 2.920 - Holíč)
Line interlocking plant	a relay semi-automatic block with a check of the line freedom and axle counter

In the interstation section there is also Hodonín stop located. It is accessible for the disabled, however, in the stop there is no ticket office. The stop is plotted in Fig. 1.

Figure 1. Hodonín Stop

In the interstation section there are 6 bridges in total, out of which 5 are located in the territory of the Slovak Republic. One of bridges is built above Morava river; it connects the Slovak and Czech Republic. This bridge was reconstructed in 2008 (Železnice Slovenskej republiky, 2018).

3. The Analysis of the Current State of Railway Transport on the line Hodonín - Holíč nad Moravou

Despite a relatively high provision of train drive and electrification this line is utilised less and less from year to year.

The number of connections of passenger transport trains has been relatively stable during its operation, influenced only with historic events (World War II.). Table 5 contains numbers of individual trains in different periods of operation since 1938 up to 2004 when the operation of passenger transport was stopped (VLAKY.NET, 2017).

Table 5. The Number of Passenger Transport Trains During a Week

Line Timetable	Holíč nad Moravou - Hodonín	Hodonín - Holíč nad Moravou
1938/1939	7	7
1941/1942	3	3
1947/1948	10	10
1950/1951	10	10
1958/1959	14	13
1968/1969	13	12
1976/1977	12	12
1979/1980	12	12
1982/1983	13	13
1988/1989	12	12
1989/1990	12	12
1991/1992	12	12
1994/1995	12	12
1995/1996	10	10
1996/1997	9	9
1998/1999	5	5
2002/2003	4	4
2003/2004	4	4

The number of trains mostly achieved 10 trains in both ways. Most of trains were driving on the line within the line timetable 1958/1959, when there in the way Holíč nad Moravou - Hodonín almost 14 trains were driving on weekdays. A sharp decrease happened within the line timetable 1941/1942, when the operation on the line was affected by the World War II. Since the 90s in the 20th century the number of connections was gradually falling down.

On September 28, 1997, i.e. when the 1st change of the line timetable 1997/1998 occurred, the operation of passenger transport was stopped at the weekends and on holidays. This operation was provided by bus transport. Since the line timetable 1998/1999 there were only 5 trains driving on the line in both ways, and in the line timetable 2003/2004 the number was reduced to 4 trains only. On December 10, 2004 the operation of passenger transport was completely stopped on the line. Performances of passenger railway transport were taken over by bus transport (VLAKY.NET, 2017).

With respect to limiting elements described in the previous part the freight transport has never been too intensive. It was the electric operation which should have provided the deviation fraction of freight trains out of RS Břeclav, which was significantly overloaded already in the late 80s. In 1991 the operation of freight transport was stopped; even that minimum number of freight trains was returned back to their original route via RS Břeclav (Tomančák, 2000).

A low utilisation of this line is proved with statistic data obtained from the directorate of ŽSR from 2011 to 2018 introduced in Table 6.

Table 6. A Summary Comparison of Performances of Railway Transport

Line Timetable	Num ber	Train-Kilometre	Gross Tonne-Kilometre	Revenues
2010/2011	724	2,178.516	73,837.851	2,048.55€
2011/2012	726	2,184.534	91,771.491	1,990.42€
2012/2013	681	2,049.129	85,657.203	1,921.02€
2013/2014	2	6.018	433.296	6,- €
2014/2015	1	3.009	147.441	3.37 €
2015/2016	2	6.018	433.296	6,- €
2016/2017	0	0	0	0,- €
2017/2018	0	0	0	0,- €

Since the 1st change of the line timetable 2010/2011, i.e. March 6, 2011, there in the railway depot Hodonín armament of engine units, series 813/913, of the carrier ZSSK, a. s., took place which provided the fraction of passenger trains in the session Kúty - Skalica in Slovakia. Thanks to this the line was utilised. Every day the armament was provided with one pair of a train set. In December 2013 the cooperation was ended and performances on this line were reduced to minimum (Tomančák, 2012).

Freight transport was provided only with engine trains of freight transport which utilised the line in case of deviations.

Since the line timetable 2016/2017 the line has been utilised only to a minimum extent, occasionally for actions of railway enthusiasts and for drives organised with Railway Museum of the Slovak Republic

4. Results and Discussions

With respect to the analysis of the current state of railway transport on the given line we have focused our research on these three areas:

- utilisation of the line for deviations while reconstructing the IVth transit corridor, namely the section Kúty - Kúty, the state border,
- restoration of passenger transport on the given line based on requirements of passengers, arising from a questionnaire research,
- change of a route of freight trains in the direction Kúty - Břeclav - Přerov, and back via the border crossing Holíč nad Moravou - Hodonín.

4. 1. Utilisation of the Line for Deviations

The line section Kúty - Kúty, the state border, is part of the IVth transit corridor and at the same time it is part of the main line of the 7th RFC corridor. Due to these reasons a complex reconstruction of the section for the speed 160 km.h^{-1} is planned.

The entire reconstruction project of the section will run simultaneously with the reconstruction of the section Devínska Nová Ves - Malacky. The whole reconstruction will be co-financed with the European Union through CEF, a tool for linking Europe (Železnice Slovenskej republiky, 2018). Figure 2 plots the site of realising the traffic closure works.

Figure 2. The Site of the Project Realisation

While realising the traffic closure works one of two line tracks will always be free. Since the traffic closure works will run on two sections simultaneously, some measures will be required in both passenger and freight transport (Šulko, 2019). Table 7 describes the traffic closure measures in passenger and freight transport as they are scheduled by the manager of the infrastructure (Šulko, 2019).

Table 7. The Traffic Closure Measures

Measures in Passenger Transport	Measures in Freight Transport
Passenger trains will be cancelled in the section Kúty - Břeclav and they will be replaced with replacement bus transport	Nex and Pn trains in the branch Štúrovo - Kúty will be re-routed through Trnava and Jablonica
For other train categories their travelling time will be extended	Handling trains in the section Kúty - Kúty, the state border, do not drive

After reducing the number of passenger transport trains to 28 trains per day, the limiting section will not be the section Kúty - Kúty, the state border, but the section Sereď - Trnava, where only 24 trains can fit according to the Book of the Throughput of ŽSR. During the traffic closure there would 52 trains in the section Kúty - Kúty, the state border, drive.

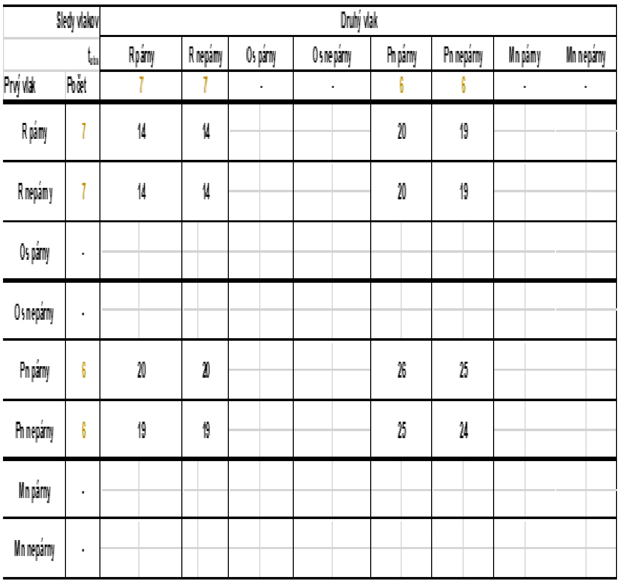
To verify the forward performance the methodology of a theoretical forward performance of ŽSR was applied; it is characterised in more details in Chapter 1. It is plotted in Figures 3 and 4.

	Sledy vlakov	Druhý vlak							
	Násobky počtov	R párny	R nepárny	Os párny	Os nepárny	Pn párny	Pn nepárny	Mn párny	Mn nepárny
Prvý vlak	Počet	7	7	-	-	6	6	-	-
R párny	7	49	49			42	42		
R nepárny	7	49	49			42	42		
Os párny	-								
Os nepárny	-								
Pn párny	6	42	42			36	36		
Pn nepárny	6	42	42			36	36		
Mn párny	-								
Mn nepárny	-								

Figure 3. Products of the Number of Trains Sequences

Time of occupancy (t_{obs}) for individual categories of trains is as follows (Železnice Slovenskej republiky, 2018):

- Ex trains share the same time of occupancy of the interstation section: 7 minutes,
- Pn train of an even direction features the longest time of occupancy of the interstation section: 12 minutes,
- Pn train of an odd direction features the longest time of occupancy of the interstation section: 11 minutes.



Sledy vlakov		Druhý vlak							
	t_{obs}	R párny	R nepárny	Os párny	Os nepárny	Pn párny	Pn nepárny	Mn párny	Mn nepárny
Prvý vlak	Počet	7	7	-	-	6	6	-	-
R párny	7	14	14			20	19		
R nepárny	7	14	14			20	19		
Os párny	-								
Os nepárny	-								
Pn párny	6	20	20			26	25		
Pn nepárny	6	19	19			25	24		
Mn párny	-								
Mn nepárny	-								

Figure 4. Times of Occupancy with Individual Trains Sequences

The direct time t_{obs} must be added with the indirect time t_{obs}, which represents an interval of crossing in RS Kúty and RS Lanžhot. In both RSs the interval will be the same - 1 minute, with respect to matching types of a station interlocking plant (electronic interlockings). The calculation of the practical throughput (n_{prakt}) is to be added with 90 minutes of time of the traffic closures ($T_{výl}$). Table 8 summarises individual resultant values which are used to make a conclusion (Gašparík & Šulko, 2016).

Table 8. Resultant Values Required for the Calculation

Indicator	Value
$\sum T'_{obs}$	12,272 min.
T''_{obs}	13,499.2 min.
T_{obs}	259.6 min.
t_{obs}	4.99 min.
t^{sk}_{medz}	22.7 min.
$t^{pož}_{medz}$ per the regulation D 24	9.4 min.
$t^{pož}_{medz} \leq t^{sk}_{medz}$	true
$\mathbf{n_{prakt}}$	**92 trains/24 hours**

When one of two line tracks is excluded, the practical throughput is 92 trains per 24 hours, which is 40 trains more than expected 52 trains per 24 hours. This implies that re-routing under a favourable operation situation will not be required, however, with respect to a stochastic nature of the railway transport industry the necessity to re-route the trains cannot be ruled out. Therefore it would be appropriate to keep the line.

4.2. Restoration of Passenger Transport on the Basis of a Marketing Survey

Using a questionnaire survey realised in 2017 - 2019 inhabitants of towns Holíč nad Moravou and Hodonín were asked for their potential interest in restoring the passenger transport. Table 9 represents places, dates and types of surveys which were realised in order to find out a potential of restoring the passenger transport.

Table 9. Realisation of the Survey

Date	Town	Type
2. 2. 2017	Holíč nad Moravou and Hodonín	Direct address in a field
4. 3. 2017	Holíč nad Moravou	
11. 3. 2017	Hodonín	
24. 6. 2018 - 16. 4. 2019	-	Internet survey

Both questionnaires contained several open questions as well as multiple-choice questions. The purpose was to find out and analyse habits of passengers before and after stopping the passenger transport, as well as the option to transit to railway transport in case of restoring the passenger transport. Altogether there were 15 questions and some space for comments in both questionnaires. Moreover, preferred selling channels were investigated. Figure 5 plots results of individual surveys.

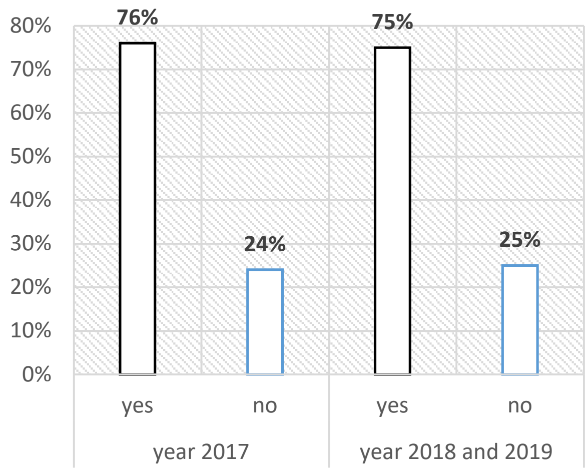


Figure 5. Interest in Restoring the Passenger Transport

The black colour is used to express the respondents' interest in restoring the passenger transport in 2017, and the blue colour is used to express the respondents' interest in restoring the passenger transport in 2018 and 2019. In 2017 the questionnaire was completed by 200 respondents, and in 2018 and 2019 the questionnaire was completed by 40 respondents. This second Internet questionnaire was only a supplementary one, serving to find out a change of the state when compared to 2017. The change in passengers' preferences was negligible.

Based on the results of the questionnaire survey there exists a potential to restore the passenger transport. A potential restoring should meet qualitative and quantitative requirements when creating the timetable. Table 10 lists some selected qualitative and quantitative requirements which are recommended to be met when creating the timetable. They should attract as many passengers as possible.

Table 10. Requirements of Timetable

Quantitative Requirements	Qualitative Requirements
Frequency of connections	Speed
Number of selling channels	Accessibility for the disabled
Number of seats	Easy-to-remember timing timetable
	Continuity of connections
	Integration

After meeting these basic requirements, the restoration of passenger railway transport would be an interesting alternative to current transport options between the towns Hodonín and Holíč nad Moravou.

4.3. Re-Routing of Selected Freight Trains

Selected freight trains driving on the route Kúty - Břeclav - Přerov could be re-routed via the border crossing Holíč nad Moravou - Hodonín after meeting the limiting conditions. There are the following limiting conditions:

- a standard of length,
- a standard of weight.

If a train passed without stopping through the section Kúty - Holíč nad Moravou - Hodonín, the standard of length would be irrelevant. With respect to the stochastic character of railway operation it would, however, be risky to ignore the standard of length. In Table 11 there are limiting conditions for the line section Kúty - Holíč nad Moravou and Holíč nad Moravou - Hodonín worked out (Železnice Slovenskej republiky, 2018).

Table 11. The Standard of Length of Limiting Sections

Section	Standard of length
Kúty - Holíč nad Moravou	530 m
Holíč nad Moravou - Hodonín	665 m

The limiting section is not the section Holíč nad Moravou - Hodonín, but the section Kúty - Holíč nad Moravou, a freight train would have to pass through. A limiting RS is Gbely, where the longest track is 530 m long. The following table contains examples of a standard of weight for selected railway tractive vehicles used most frequently by carriers (Železnice Slovenskej republiky, 2018).

Table 12. The Standard of Weight for Selected Locomotives

Section	Type of Resistance	Locomotive Series	Standard
Kúty - Holíč and back	S	230, 363	2,000 t
	T		2,200 t
	S	E 189	2,400 t
	T		2,600 t
Hodonín - Holíč	S	230	2,200 t
	T		2,500 t
	S	363	2,200 t
	T		2,500 t
	S	363.5	2,350 t
	T		2,800 t
Holíč - Hodonín	S	230	1,600 t
	T		1,800 t
	S	363	1,600 t
	T		1,800 t
	S	363.5	1,700 t
	T		2,000 t

The standard of weight was determined for locomotives, series 230 and 363, always with one active locomotive. These are the most often used types of locomotives by Slovak carriers. Besides, series 210, 740, 742, 753, 754 and others are also allowed to transit through the border crossing.

The biggest standard of weight is 2,800 t in the section Hodonín - Holíč when the locomotive, series 363.5, is used.

Conclusion

Regional railway transport is an important part of the national transport system. Despite some regional lines have been showing a low utilisation for longer time it is necessary to study their effectiveness with regard to synergic effects. Our research has shown that the line in question has its potential; moreover it is electrified with an alternate voltage system 25 kV/50 Hz, which increases its options of utilisation and at the same time it represents an environmental alternative to road transport.

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INTERNATIONAL COMPARISON AND TREND OF EMISSIONS IN THE TRANSPORT SECTOR IN THE EUROPEAN UNION AND SLOVAKIA

Abstract. Transport and its major part of transport means is currently based on the internal combustion engine principle. For these engines, the primary energy source is oil, natural gas, coal, biomass and others. These primary energy sources and their processing in refineries and factories are used to produce products that are used to drive engines - fuels. From what energy sources these fuels will be produced and what technology will be used to process and produce them is also an important. This whole process must take the reduction of total emissions into account. Future fuels can be considered synthetically produced diesel or hydrogen, which can later significantly affect the decrease in emissions from their processing, production and subsequent combustion of these more environmentally friendly types of fuels. This article processes analyses and development of basic pollutants, total emissions and energy consumption in the Slovak Republic and the EU. In the second part there is an evaluation of the emissions trend development in transport in the EU and Slovakia.
Keywords: emission, pollutants, transport, environment, comparison

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Introduction

Today, efficient energy performance and improved environmental practices are becoming an important quality criterion in transport services. Suppliers of transport services are required to declare the impact of their activities on the environment, by quantifying the specific amount of pollutants produced and emissions from vehicle transport operations. Nowadays, one of the main pollutants nowadays is the worldwide known greenhouse gas carbon dioxide - CO_2. Its production is gradually decreasing from year to year, but some countries still have difficulty in reaching the emission limits set by the European Union.

1. Comparison of the development of the main pollutants in Slovakia and the EU

In the long-term range between 1990 and 2016, there was a significant decrease in total emissions from the economy. Since 1990, a decreasing trend has been observed for all pollutants monitored.

In the mid-term review since 2000, the decreasing trend continued for most of the monitored substances and the development can be considered positive. There was a slight increase in NMVOC, SO_2, $PM_{2.5}$, POPs (emissions of persistent organic pollutants from industrial processes) and also in the case of Cd (cadmium) emissions in the year-on-year change occurred in 2016 - 2017. Overall, the Slovak Republic has been successful in meeting the objectives of its international commitments. A summary assessment of the development of emissions of basic pollutants for the period 2000 - 2017 is shown in the following figure.

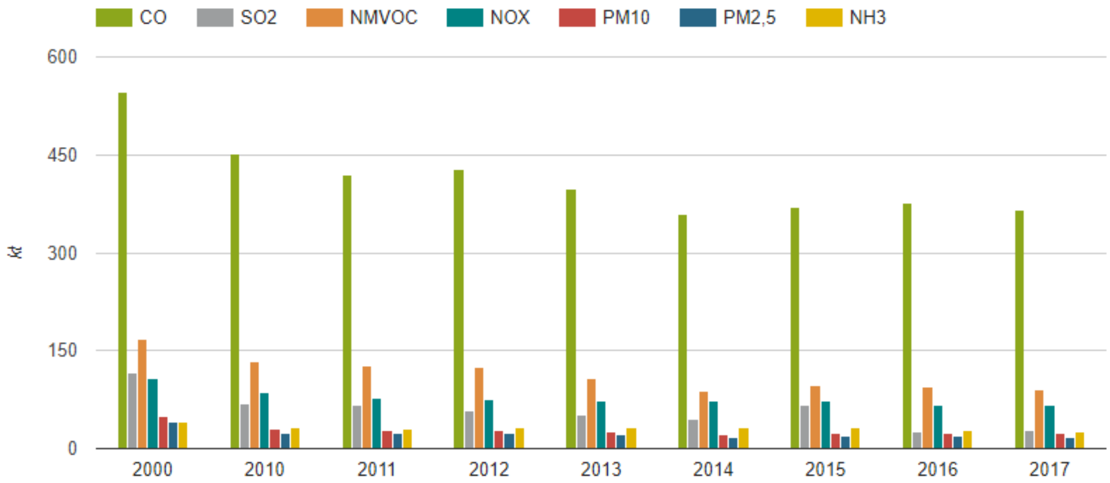
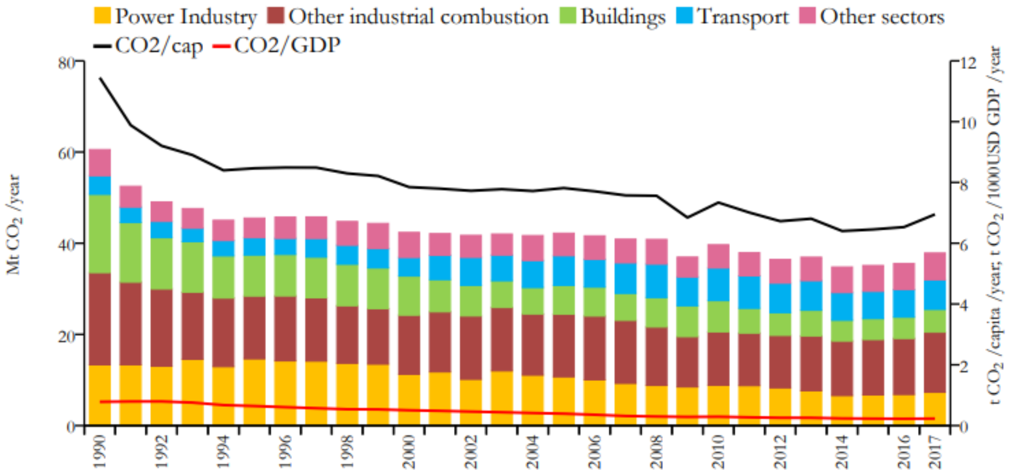


Fig. 1. Trend of emissions of basic pollutants in Slovakia



Year	Mt CO_2/yr	t CO_2/cap/yr	t CO_2/kUSD/yr	Population
2017	37.855	6.949	0.231	5447662
2005	42.194	7.815	0.392	5398963
1990	60.537	11.447	0.782	5288454

Fig. 2. Fossil CO_2 emissions by sector during 1990-2017 in Slovakia

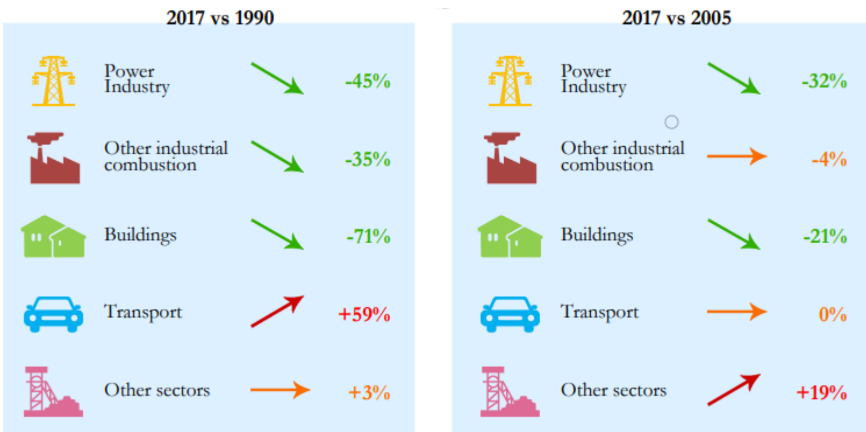


Fig. 3. Change fossil CO_2 emissions by sector during 1990-2017 in Slovakia

In the long-term interval (1990 - 2016), there was a significant decrease in BP (Basic Pollutants). A comparison of the years between 2000 - 2016 showed a decrease in SO_2 emissions by up to 78.5 %, NO_X by 40.9% and CO 36%. The trend in particulate emissions in the period 2000 - 2016 was decreasing, by 23 % for PM_{10} and by 14.8 % for $PM_{2.5}$.

One of the reasons for this positive development was legislative and technological progress and a change in the fuel base. The development itself was also affected by a change in the structure and volume of industrial production.

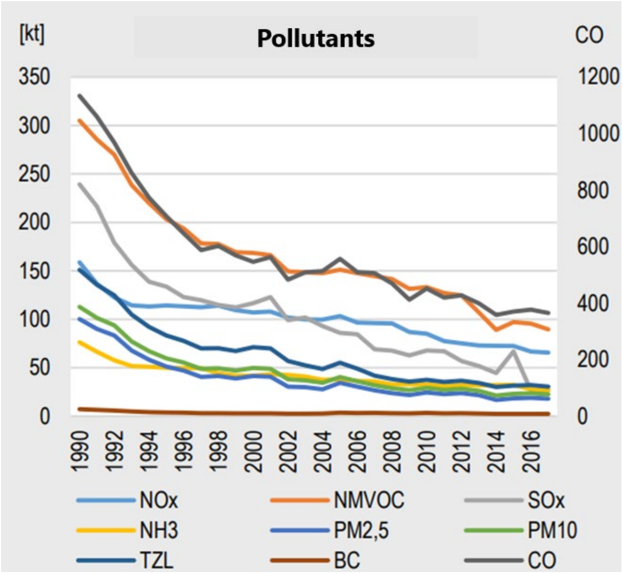


Fig. 4. Trend of emissions of selected pollutants in the Slovak Republic in 1990-2017

A comparison of the base year 2005 emissions and the currently available year 2017 emissions of selected pollutants NO_X, NMVOC, SO_X, NH_3, $PM_{2.5}$, PM10, TZL(solid pollutants), CO broken down by economic sectors is shown in Figure 5. The graphs show the percentage share of emission of individual sectors nationwide balance sheet.

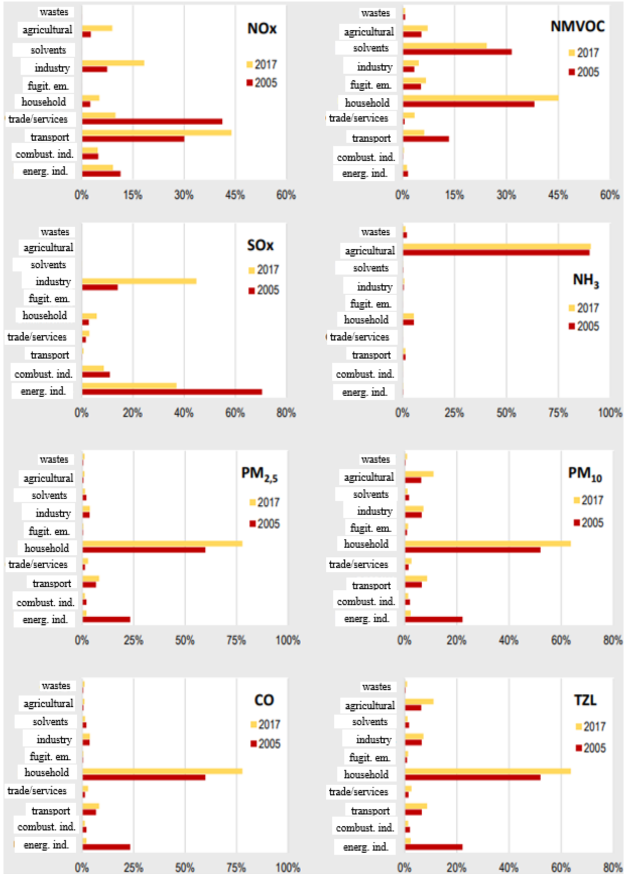


Fig. 5. Overview and comparison of shares of individual sectors in national totals

The following three figures show an international comparison of emissions (PM_{10}, SO_2, NOx, NMVOC, NH_3) of individual EU countries for 2016.

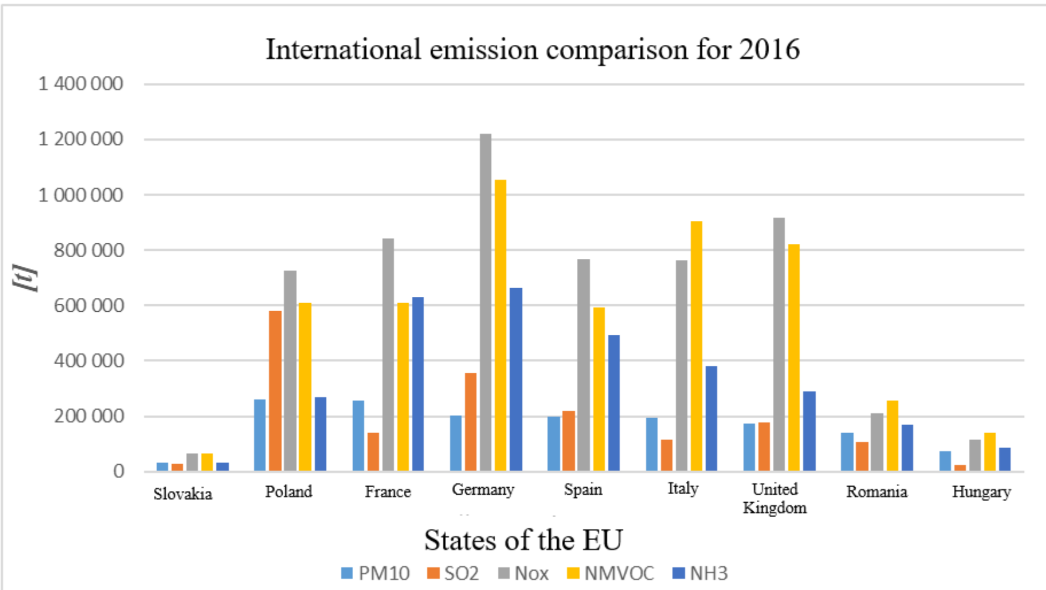


Fig. 6. International comparison of emissions of EU countries for 2016

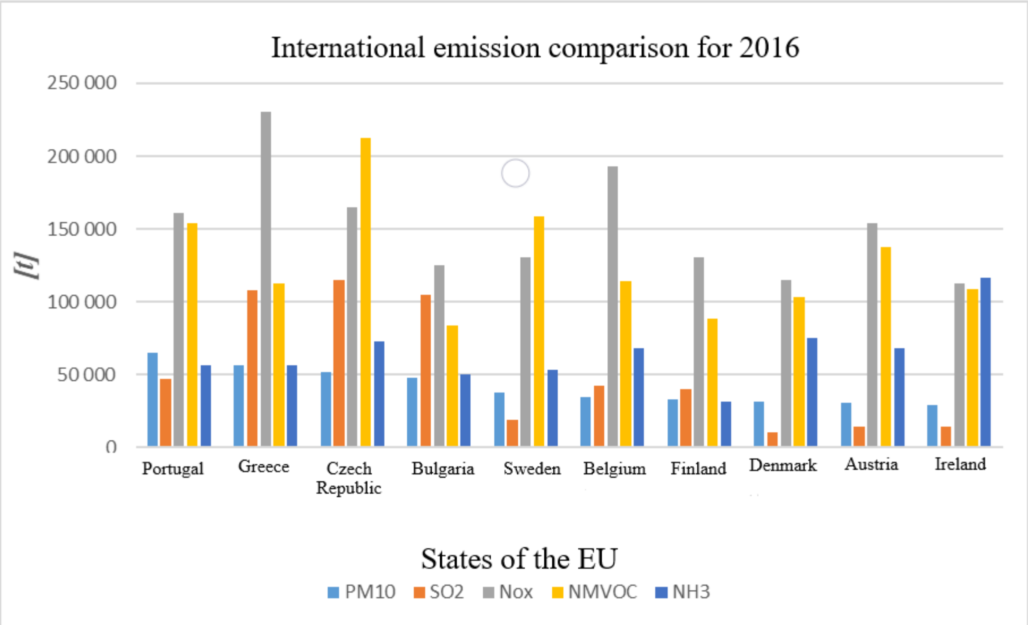


Fig. 7. International comparison of emissions of EU countries for 2016

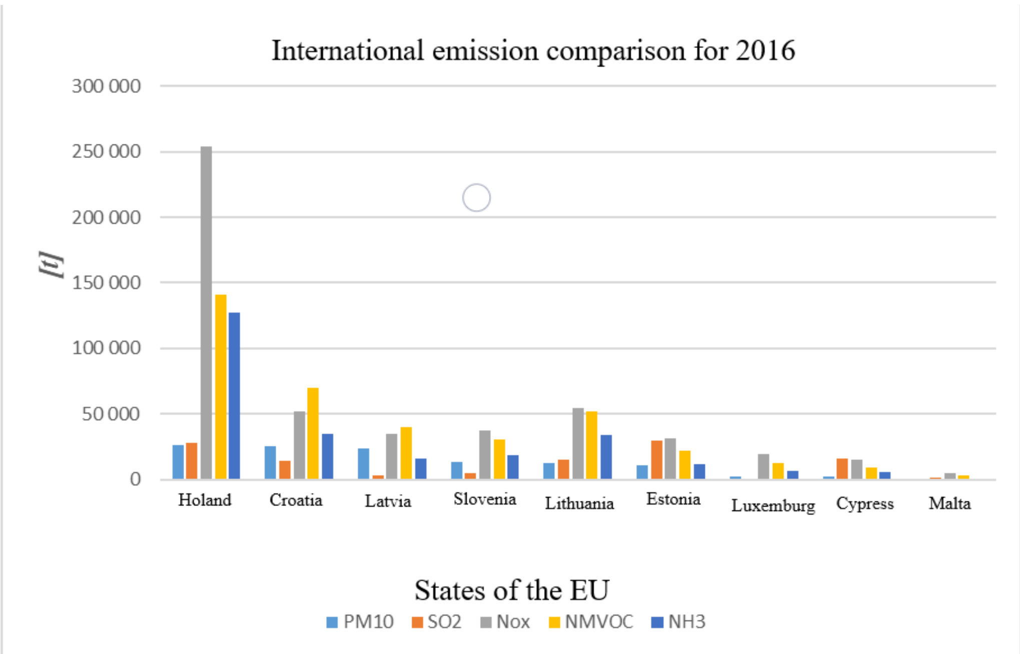


Fig. 8. International comparison of emissions of EU countries for 2016

2. Development of final energy consumption by 2017

Road transport accounts for the largest share of total liquid fuel consumption in the transport sector, while final electricity consumption is attributable to rail transport. The share of renewable energy (RES) in the transport sector in 2016 was 7.5%. The final energy consumption for the period 2001 - 2016 in the transport sector is shown graphically in the following figure.

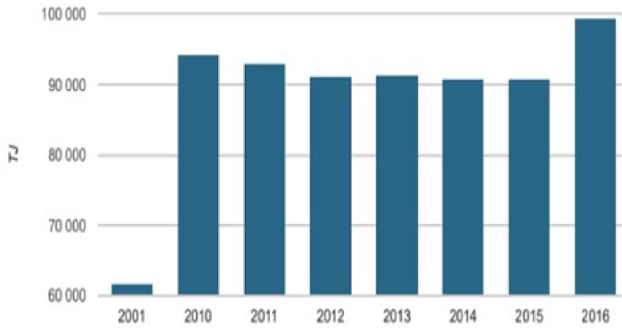


Fig. 9. Final energy consumption in transport in Slovakia

Final energy consumption in the transport sector increased by 61% between 2001 and 2016, despite a volatile trend. The largest share of fuel consumption in the transport sector is the final consumption of liquid fuels (97%), while the share of final consumption of solid fuels, gaseous fuels and electricity is smaller.
The growth of final energy consumption in the transport sector continued also in the following period of 2001 - 2017. Road transport had the largest share in fuel consumption. In rail transport, electricity consumption predominated.

2.1. Development of transport performance in the transport sector

In 2017, the number of transported passengers in rail and air transport increased, while road public transport and water transport recorded a more significant year-on-year decrease in the number of transported people. Transport performance compared to last year recorded a slight increase in all types of passenger transport. The share of individual transport modes in passenger transport performance is represented by individual motoring - 72%, road public transport - 13%, rail transport - 10%, public transport - 3% and air transport - 2%.

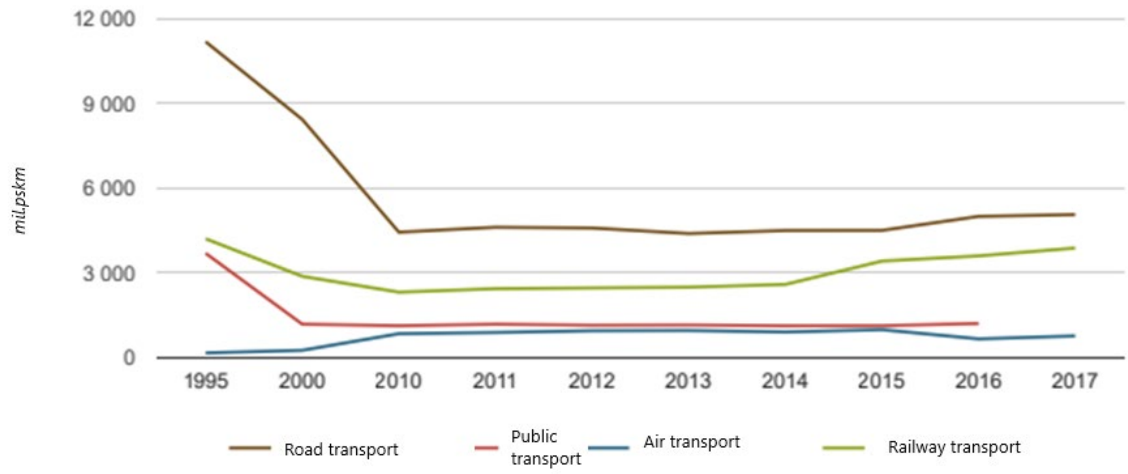


Fig. 10. Transport performance in passenger transport by type of transport in Slovakia

Freight transport performance decreased in 2017 in all transport modes except air transport. Road transport (about 79%) accounts for the largest share of freight transport performance, followed by rail (19%) and inland waterway transport accounts for only 2%.

Fig. 11. Development of transport performance in freight transport by type in Slovakia

Public transport is provided by transport companies in Bratislava, Košice, Prešov, Banská Bystrica, Považská Bystrica, Púchov and Žilina. In other Slovak cities, public transport is provided by road passenger transport companies, i.e. private businesses. Such transport is not kept as public transport. In 2017, there was a year-on-year increase in the number of people transported by bus and trolleybus urban public transport. Transport of people by tram decreased year-on-year. During the period under review, bus transport keeps the leading position in passenger transport, followed by tram and trolleybus transport.

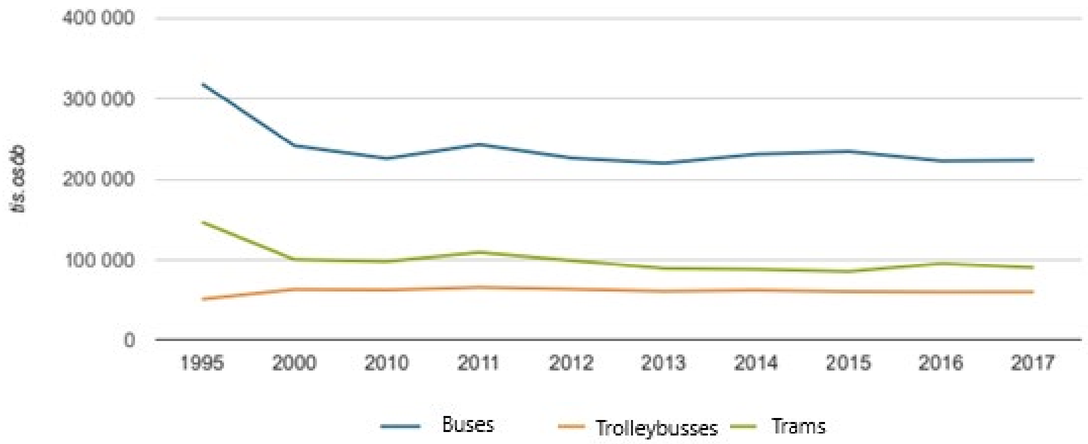


Fig. 12. Development in the number of transported persons by public transport in Slovakia.

The transport sector is considered as a significant source of emissions of nitrogen oxides (NO_X) and carbon monoxide (CO) not only in Slovakia but also globally. Road transport has the largest share of transport emissions, dominated by the use of both diesel as well as passenger cars.

3. Evaluation of trends in transport emissions in the EU and Slovakia

The share of transport in total EU greenhouse gas emissions is increasing. About a third of transport emissions are generated by trucks and bus. In Slovakia it is even more - up to 45%. According to the European Environment Agency, in the current trends, transport is not able to meet the climate commitments resulting from the Paris Agreement.

In May 2018, the European Commission proposed emission limits for trucks, representing 27% of CO_2 emissions from road transport in the EU 28. Road transport's share of total greenhouse gas emissions is increasing, and therefore reducing transport emissions is an important part of climate plans.

Trucks and bus transport will produce 1/3 of CO_2 emissions from road transport and 7% of total greenhouse gas emissions in the EU 28. In Slovakia it has been around 45% in the long term, well above the EU18 average. In addition to transport, industry and energy sectors has the largest additions in the total emissions.

The following figures show a comparison of the share of transport in total emissions by 2016 in the EU and the Slovak Republic.

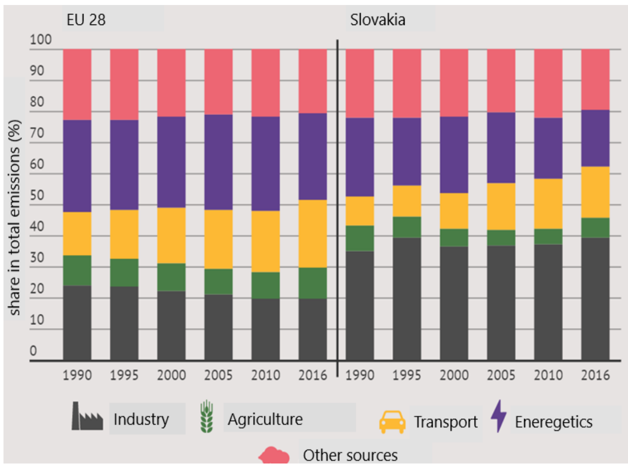


Fig. 13. The share of transport in total emissions in the EU and Slovakia

The following figure graphically shows the share of individual transport modes in the total amount of emissions from transport in the EU and the Slovak Republic. It is clear from the chart that the greatest share of air pollution in both cases is accounted for by individual car transport and the smallest share is contributed by rail transport.

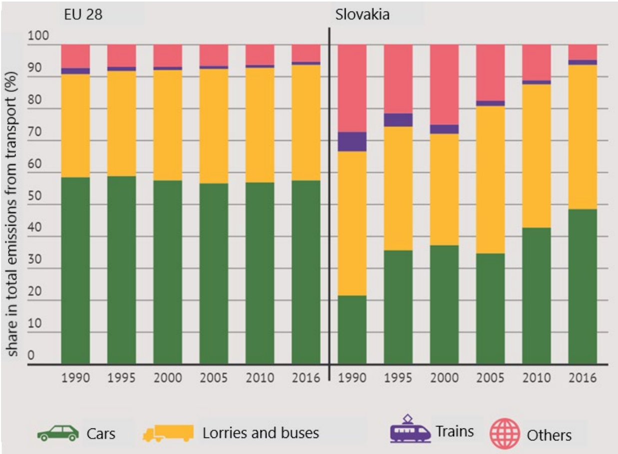


Fig. 14. Share of individual types of transport in total emissions from transport in EU and SR

Road transport is an economic sector that is developing worldwide on most indicators such as fuel consumption, i.e. the number of cars and transport performance considerably faster than GDP growth (this also causes and increases the associated environmental and health damage). In total, it has a negative impact on all environmental elements. To a large extent the air is affected by the combustion of hydrocarbon fuels in internal combustion engines of vehicles and also by increased noise emissions as one of the significant risk factors. Negative changes in the traffic situation mainly occur in cities and residential areas, i.e. areas close to exposed traffic routes, where the environmental burden and the health condition of the population are increased.

3.1. Development of emissions in the transport sector in Slovakia

In recent years, the development of emissions in the transport sector in Slovakia has seen a significant change in the use of public transport and its replacement by passenger cars. Simultaneously, the level of transit traffic (trucks) has also increased. Fuel consumption in rail transport has been increasing only slightly in recent years compared to road transport, which has seen a much steeper increase. Compared to 2005, emissions of pollutants decreased from 8% (sulphur oxides - SOx) to 81% (carbon monoxide). Simultaneously, heavy metal emissions increased significantly by 29% and POPs by 63%. Most heavy metal emissions come from wheel abrasions, roads and brakes, which are emissions unrelated to the combustion of fuels. Increasing traffic intensity and aggressive driving have a significant impact on the increase in these emissions.

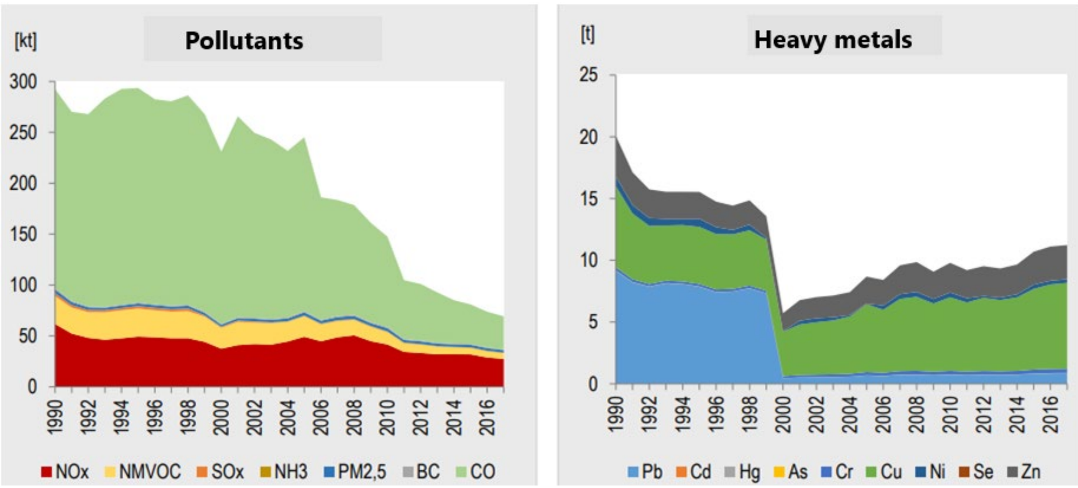


Fig. 15. Development of pollutants in the Slovak Republic in the transport sector in 1990-2017

Emissions that are not visible in the graphs are still produced by the processes, but at a much lower rate than other pollutants. However, for some substances, even small amounts may be significant.

Conclusion

The transition to greener transport in cities is facilitated by lower vehicle size requirements and higher population density. Public transport has more choices, and cycling and walking join that. The biggest problems of cities are congestion, poor air quality and noise. Urban transport accounts for approximately one quarter of CO_2 emissions from transport and 69% of traffic accidents occur in cities. The gradual phasing out of 'conventionally powered' (using non-hybrid internal combustion engines) vehicles from the urban environment contributes most to a significant reduction in oil dependency, greenhouse gas emissions, urban air pollution and noise. This procedure will need to be complemented by the development of suitable fuel / charging infrastructures for new vehicles.

Increasing the share of travel in public transport, together with minimum service obligations, will make it possible to increase the density and frequency of transport services and therefore create a positive chain reaction in the various public transport modes. Spatial planning can also contribute to reducing traffic

Acknowledgements

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APPLICATION OF RAILWAY SAFETY SYSTEM RADIOBLOCK

Abstract: This paper focus on description of railway safety system radioblock and its application. Content of the paper describes usefulness of this system on those railway lines, which have been operated according to norm about simplified supervision of railway operation. Theoretical basis of the research is proved by case study on the railway line Číčenice – Volary (Czechia). This railway line is the only railway line with this safety system nowadays. Application of these issues is evaluated from safety and technology point of view. There are some suggestions for other railway lines, which are suitable for radioblock railway safety system.
Keywords: railway transport, railway infrastructure, safety system, radioblock

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Introduction

Railway transport is considered as fast, safe and comfortable way of transportation. Safety of railway operation is one of the main and factor with significant impact on the quality of passenger transportation and freight transportation too. Level of safety on railways is influenced by railway safety system, what is a complex of technical equipment and administrative arrangements. The main task of railway safety system is to eliminate all failures caused by people. (Gašparík, et al., 2017)

Safety system radioblock is one of many types of safety systems, which are used on railway lines. There are described its components and functionalities on each level of the safety system. Evaluation of this safety system compared from safety and technology point of view. The comparison is focused on railway operation on selected route Číčenice – Volary according to norms of Czech railway infrastructure manager SŽDC D3 and SŽDC D4. Railway line Číčenice – Volary was operated as simplified supervision of railway operation therefore there was not any safety system. Incidence of some extraordinary events led to make the safety system on this railway line. Czech railway infrastructure manager SŽDC wants to prevent such extraordinary events in the future.

1. Radioblock description

Radioblock RBA-10 is the complex of technical equipment and administrative arrangements, which create the system for managing and securing the railway operation mainly on regional railway lines. This system was made for increasing the level of safety on these railway lines and to prevent all failures made by people. This system is created with minimum investment and operating costs. It is intended for usage on one-track railway lines with maximum speed 100 km/h. Maximum number of traffic control points is 35 and maximum number of trains is 16 in one moment. In all traffic control points the maximum number of tracks is 4. Radioblock system is based on radio communication between radioblock headquarters and vehicles. (Brejcha, 2009)

Some of the basic functions provided by technical parts in RBA-10 facilities are:

1. Rejection of conflict permissions such as train rides to opposite direction on one track,
2. Actual conditions of the whole area are displayed to dispatcher of the radioblock,
3. Electronic transport documentation and data could be transferred,
4. Conditions of downloaded permissions are displayed to vehicle-drivers,
5. Rejection of train ride without permission and control of vehicle-drivers' acts connected to location of the train according to permission by using GPS with warning signals,
6. Control of basic condition on infrastructure in railway stations,
7. Possibility of emergency STOP signal,
8. Possibility for operation of railway vehicles without radioblock facility by substitute acts of dispatcher.

Radioblock headquarters is a complex of technical equipment situated in the dispatching centre. Its purpose is to control train rides in the selected area. It enables sending data and voice permissions for vehicle-drivers. Radioblock vehicle facility is a complex of technical equipment which display permissions from dispatcher directly to vehicle-driver. Train location is also available there. Basic parts are actuating device connected to display.

Basic level of radioblock railway safety system is signed as RB 0. Added Satellite navigation creates level RB 0+. Another level RB 1 uses GNSS. Radioblock level RB 2 means that there is exact control of permissions by measuring the ridden distance. This level of radioblock is not practically used. Radioblock facility in the vehicle has these functions:

1. Automatic check-out,
2. Control of permissions and its compliance with possibility of emergency break activation,
3. Maximum speed limit,
4. Actual speed with possibility of emergency break activation,
5. Integrity of the train,
6. Simple train login,
7. Conditions of crossing safety systems ,
8. Information about contemporary speed restrictions.

In the conditions of railway transport, it is not possible to ensure continuous GNSS signal because there are tunnels, deep forests etc. For this reason, on the radioblock facility in the vehicle, there can be switched the level of its functionality. Current level must be shown to vehicle-driver on the display.

Table 1. Threats and their prevention according to the radioblock level of functionality

THREAT	RB 0	RB 0+	RB 1	RB 2
Incorrect permission	YES	YES	YES	YES
Departure without permission	YES	YES	YES	YES
Incorrect train location	NO	WARNING	YES	YES

Organising of railway transport operation on the railway line, where Radioblock railway safety system is implemented, is provided by permission to train ride. This permission is issued by dispatcher and then it is delivered to the vehicle facility by radio data network. This permission is displayed by vehicle facility therefore it is necessary to have this facility on each vehicle, which are riding on that railway line. (Brejcha, 2009)

Spatial sections on the railway line with radioblock railway safety system is divided by station borders. In front of each station on railway line with radioblock railway safety system, there must be entrance signal with its foreboding. On these signals, there must be number of that railway track in the station, where train is going to arrive in basic conditions. Symbol X is used in that case, when the station is managed from radioblock dispatching centre. Every train on the railway line with radioblock railway safety system, must be recorded and logged into radioblock dispatching centre. Login can be done electronically or vocally. From the beginning of the login until the logout, the status of the vehicle is recorded, and this status is known as mode.

Table 2. Modes and data permissions overview

Mode	Explanation
No permission	Departure of the vehicle will stop the vehicle
Permission to ride	Train can ride on selected railway section
Vehicle-driver responsibility	Ride according to vocal permissions
Shunting	Permission for shunting in the station

Fig. 1. Radioblock vehicle facility

2. Railway line Číčenice - Volary

Railway line is signed by number 197 in SŽDC timetable. The beginning of this railway line is in the railway station Číčenice. There is another electrified railway line number 190 České Budějovice – Plzeň, where long-haul trains are also operated. In railway station Volary, there is other railway line number 198 Strakonice – Volary. In railway station Černý Kříž, there is other railway line number 194 České Budějovice – Černý Kříž. The entire end of this railway line is in the station Nové Údolí. Overall distance of the railway line is 70 km. In the section Číčenice – Volary, railway transport is operated according to norm SŽDC D4. In railway stations Číčenice and Volary, there are dispatchers therefore these railway stations are autonomous. These dispatchers organise primarily railway transport in those railway stations. Dispatching centre for radioblock railway safety system on this railway line is in the station Prachatice, which is also autonomous station. It means that dispatcher of radioblock centre is also a dispatcher for this railway station. (Schreier, 2004)

3. Railway safety system purpose

Safety is the dominant criterion of transportation. It is generally guaranteed by norms, licences, permissions, certificates and verifications. Transportation safety is measured by indicator of accidents per one billion passenger-kilometres – number of passengers transported per one kilometre. According this way statistics, railway transport is one of the safest modes of transportation. (Kampf, et al., 2012)

Main goal of the radioblock railway safety system is to increase the level of safety in railway operation on regional railway lines. In conditions of Czechia, it is determined for railway lines, where railway operation is done according to norm SŽDC D3. On railway lines with simplified supervision of railway operation, the whole responsibility is on operational staff. There is not any railway safety system therefore the railway transport operation is done by supervising of competent person. Telephonic communication between dispatcher and vehicle-driver is recorded. Every mistake such as departure from station without permission could have fatal consequences. (Zitrický, et al., 2015)

There were some extraordinary events on the railway line Číčenice – Volary when this railway line was operated according to norm SŽDC D3 until year 2011. This was the main reason to build radioblock railway safety system on this regional railway line. Most of accidents was caused due to mistake of people therefore railway safety system could prevent these accidents. Reasons of these accidents were departures from station without permission or mistakes in communication.

Table 3. Extraordinary events on this railway line

Year	Event	Death / Injury	Costs (€)
2004	major accident	2 / 33	160 000
2007	major accident	0 / 13	5 500
2011	major accident	1 / 15	280 000
2013	accident	0 / 0	10 000

4. Technology of railway operation

On each railway line with simplified supervision of railway operation, there is on railway station, from where the dispatcher organises the whole railway line. This dispatcher provides permissions for ride to every train, which is on the railway line. All trains on that railway lines have recording obligation in selected traffic control points. These traffic control points are stated in special timetable for vehicle-drivers. In case of shunting, dispatcher must set exact time for shunting. After the end of shunting, vehicle-driver must report that tracks are free. Railway line with radioblock railway safety system (norm SŽDC D4) is supervised by dispatcher, who provides all permissions for each train in selected area. Contrast to railway lines with simplified supervision of railway operation, there is a safety system, which eliminates mistakes of people. (Černá, at al., 2016)

Besides increased safety of railway operation, radioblock railway safety system has also other positive impacts to quality of passenger transportation. Duration of operational intervals in every station were decreased therefore traveling time was also decreased. In every traffic control points, there were built new platforms for each direction. New platforms have level crossings with tracks. These platforms are 250 mm above the track according to norm 398/2009 General technical requirements for people with reduced mobility, better known as TSI PRM. There was also build new lighting system in each traffic control point with photocell and video recording system. Information about arrivals, departures, delays and extraordinary events are provided for passengers by special radio system. This system is controlled by radioblock dispatcher in railway station Prachatice. There were not so great decreases in traveling time due to connected trains on other railway lines. Traveling time can be decrease by radioblock railway safety system on this railway line only in case of:

1. Increase the speed limit from 60 km/h to 100 km/h,
2. Decrease static parts of operational intervals in railway stations.

5. Radioblock on other railway lines

On the SŽDC railway network, there are 82 railway lines, which are operated according to norm SŽDC D3. Some of these railway lines do not need radioblock railway safety system because operation on those railway lines is not so high. There is only one traffic control point or there is only one vehicle on the whole railway line. Some of these railway lines are without any regular traffic. On the other hand, there are many railway lines, which are not so suitable for norm SŽDC D3 because of rush traffic or many control points.

Table 4. Railway lines suitable for radioblock

Railway line	Km	Ctrl points
Vimperk – Volary	37	3
Strakonice – Vimperk	32	4
Chornice – Třebovice v Č.	36	3
Kostelec n. H. – Chornice	34	3
Kostelec n. H. – Senice n. H.	19	2
Teplice n. M. – Trutnov střed	32	4
Blatno u J. – Bečov n. T. + Protivec – Bochov	76	8
Mar. Lázně – Karlovy Vary d.n. + Kr. Jez – H. Slavkov-Kounice	59	9
Nejdek – Potůčky	27	4
Mělník – Mladá Boleslav hl.n.	49	4
Suchdol n. O. – Budišov n. B.	39	5
Bělá n. R. – Tachov	40	3
Domažlice – Bělá n. R.	37	2
Jindřich. Hradec – Nová Bystřice	30	9
Jindčichův Hradec – Obrataň	44	9
Choceň – Litomyšl	24	4
Vsetín – Velké Karlovice	27	3
Rybník – Lipno and Vltavou	22	4
Čáslav m. n. – Třemošnice	17	4
Tanvald – Harrachov st. hr.	13	4
Pňovany - Bezdružice	24	4
Jilemnice – Rokytnice n J.	16	4

Evaluation of railway lines in Czechia, which are suitable for radioblock railway safety system, was done according to determined criteria:

- Number of traffic control points on the railway line,
- Length of the railway line (km),
- Current regular traffic,
- Train crossings in traffic control points.

Proposed railway lines are suitable for radioblock railway safety system. Radioblock can increase the safety of railway transport operation and throughput of the railway line. It is also possible to decrease traveling time. It is necessary to have radioblock vehicle facility on each vehicle, what increase costs for transport companies. Disadvantage of using radioblock is still opened problem of connection between regional railway lines and main railway lines, where is European traffic control system – ETCS. (Šrámek, et al., 2018)

Conclusions

1. Railway safety system radioblock is built for those regional railway lines, where simplified supervision of railway operation according to norm SŽDC D3 is used now.
2. Radioblock railway safety system is provided on various levels. The highest level is connected to satellite systems GNSS for identification of exact train location. Using of GNSS is cheaper than using of location equipment on the track.
3. There is possibility to increase maximum speed on the railway line to 100 kph. Traveling time can be decreased and some technological tasks in railway stations are not necessary.
4. There is only one railway line with radioblock railway safety system. It is railway line Číčenice – Volary in Czechia. Occurrence of extraordinary events on this railway line led to building of this safety system. Another railway line Dolní Bousov – Kopidlno is ready for building updated version of radioblock railway safety system.
5. In Czechia, there are many railway lines suitable for radioblock railway safety system. These railway lines were proposed according to selected criteria. They are not suitable for simplified supervision of railway operation because of high number of stations or rush traffic on them.

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DEVELOPMENT AND CURRENT TRENDS IN THE USE OF MOBILE DEVICES

Abstract. The paper deals with the analysis of the development of mobile devices and current trends in their use and development. The relevance of the article is in its linking history and present. The article points to milestones in historical development and future trends and development of mobile devices. Today, mobile devices affect all areas of human life, whether private or business. Mobile devices are now able to replace computers and laptops, so the user has the information they always have with them. The development of mobile devices inherently includes systems supporting their functioning, which the article also discusses.
Keywords: the mobile device, historical development, actual trends, the components of mobile devices

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Introduction

The current stage of the company's development is most often characterized by an exponential increase in new information, even an exponential increase in new scientific information. Technological production and societal processes are now based on in-depth scientific results, which is reflected in economic performance and competitiveness in a particular area. In this context, information and communication technologies have an irreplaceable role.

The following sections will analyze the development of mobile devices in a historical context, developments in development as well as current trends in the use of these devices.

1. The definition of the mobile device

The mobile device is a computing device small enough to be held and operated in one hand. The definition of a mobile device says it is a small electronic wireless device with its own power supply and various applications. Typically, each mobile device has a flat LCD interface that includes a touch interface with digital keys and a keyboard or physical keys together with a physical keyboard. The power source for the proper functioning of such a device is usually provided by a lithium battery. Figure 1 shows an example of lithium batteries used in mobile devices.

Fig. 1 Lithium batteries used in mobile devices

Mobile devices can be triggers for mobile operating systems that allow you to install and run third-party applications that specialize in these features (schedules, internet banking, maps, etc.). The current mobile devices are equipped with several functional accessories that create a compact unit for complex communication with the environment using multiple communication channels.

Mobile devices are most commonly equipped with the following accessories:

- integrated camera,
- digital media player
- phone calls
- video calling,
- GPS functions.

Mobile devices are also used in various areas of the work environment.

For the use of applications related to individual requirements of the transport market segments, the following mobile devices can be used:

- mobile phone - especially smartphone,
- Laptop or smartbook
- PDA.
- tablets.

The mobile phone is a portable electronic device designed for voice, text, image and data communication. The device is radio-connected to the telephone network and therefore the phone is only usable for communication in an area that is covered by the mobile network (it cannot be used in tunnels or in dense wooded areas). Mobile phones have different functions (Dlugoš, 2017, p. 14).

In addition to telephony, the following devices are available:

- connect to the Internet,
- browse websites,
- send and receive text and multimedia messages
- organize meetings and create timetables.

They can be connected to other devices via infrared, bluetooth, NGC, Wi-fi or data cable. These connectivity options vary depending on the type and age of mobile phones. The operation and functioning of mobile phones is also different depending on the operating system, manufacturer and type (Chvostál, 2016, p. 22).

2. Historical development of mobile devices

The first mobile multifunction devices began to enter the European market at the end of the 20th century, but great progress in sales and normal use began in the early 21st century. They were operated with a closed operating system or other specific solution.

Mobile releases have caused a huge boom in the trading market around the world in recent decades. Over the years, the luxury convenience, which was designed for the few chosen, has become a common tool for all ages, making life and work easier and better in many ways. The ability to connect with your loved ones at any time and anywhere has become a reality that has in many ways influenced and continues to have a significant impact on people's lives.

2.1. The origins and development of analog networks 0. Generation

One of the first pioneers of wireless transmission was D. E. Hughes, who in 1879 was able to generate and capture signals transmitted by radio waves (Developer Library, 2012).

Almost ten years later, in 1888, German scientist Heinrich Hertz confirmed Maxwell's theory and experimentally demonstrated that some kind of wireless transmission between two remote devices using air as a transmission medium could be considered (Allen, 2013).

Using these principles, the Italian Guglielmo Marconi designed and operated the first radio system and obtained a patent for it in 1897. In fact, however, Nikola Tesla patented the same invention several years earlier. In 1901, Guglielmo Marconi transmitted the signal across the Atlantic Ocean and the radio was successfully used in shipping (Application Developers, 2011).

Marconi's radio only allowed transmission of telegraph sequences, but not voice. R. Fesseden, who designed a complete system for wireless transmission and reception of radio signals using the then revolutionary amplitude modulation (Developer Library, 2012), contributed to the voice transmission.

Mobile networks of the 0 th generation were unable to use the allocated spectrum efficiently, and as a rule one city was served by only one broadcasting antenna with 25 channels, which allowed a maximum of 25 participants to suddenly serve (Developer Library, 2012).

The following generation networks fall into the 0th generation of mobile networks (BlackBerry 10 Platform Choise, 2013):

- Mobile Telephone Service (MTS)
- Improved Mobile Telephone Service (IMTS)
- Advanced Mobile Telephone (AMTSO)

These networks were not very popular, but served as an important basis for next generation networks. The main problem was the infrastructure of these networks itself, which did not allow any roaming and also the possible number of subscribers, which was very small (BlackBerry 10 Platform Choise, 2013).

During the 1950s and 1960s, all companies in the telecommunications market focused exclusively on the development and research of the cellular network. Bell was headed by a patent application in December 1971 for patenting a mobile telecommunications network, which was recognized the following year, but the Federal Communications Commission (FCC) was only five years later in 1977 (Developer Library, 2012).

Mobile phones belonging to the 0 th generation were predominantly mounted in cars due to their use and size. One of the first public telephones capable of connecting to the public network was launched in America in early 1946 (IOS Developer Library, 2012). Figure 2 is a diagram of a car in which a mobile phone has been installed.

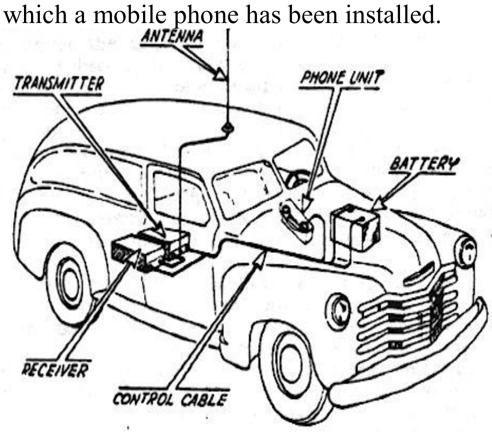

Fig. 2 The mobile phone in the car *(IOS Developer Library, 2012)*

The entire mobile device consisted of a transmit and receive block, which were connected by a data conductor to a control block containing a handset and a microphone. These devices weighed tens of kilograms (IOS Developer Library, 2012).

By far the most revolutionary novelty was launched just before 1960 and was called "Duplexer". It was the device that allowed the first full duplex transmission. It contained a frequency filter that made it possible to transmit and receive a signal using one antenna at the same time (IOS Developer Library, 2012).

The second novelty introduced in 1960 was the implementation of a dial pad in the control panel. This device enabled the user to directly dial the called number, so there was no need to notify the called number to the operator (Čamaj & Gašparík, 2011).

With the advent of the new IMTS mobile network after 1960, manufacturers have gradually introduced their new car systems with full IMTS support. They were labeled "MJ" and one of the first was again from Motorola. It became the most typical and most used control block between 1964 and 1980 (Červinka, 2007). Figure 3 shows a 1963 Motorola mobile control block.

Fig 3 Mobile control block

The development of a transistor, which fully replaced the mechanical relay, brought the first wave of miniaturization to mobile phone manufacturers. By the end of the 1960s, the first "attaché case telephones", also referred to as briefcase mobile phones, came to the market. Most of the first briefcases only supported the MTS network. These mobile phones were very heavy and were equipped with nickel-cadmium (NiMh) batteries that had a capacity of only a few hours. The transmit, receive, and control blocks, along with the battery, were placed in a briefcase. The antenna was realized by foil tapes glued between the inner leather layer and the outer lining of the trunk case (Červinka, 2007).

One of the first briefcase phones was introduced by Livermore, the LAP1000, which was a virtually conventional MTS phone placed in the briefcase. The following LAP-2000 model fully supported the MTS network as well as the IMTS network, thanks to the switch that determined which of the two networks would be used for the call. With the network selected, the dial-up telephone number length was changed to 5 digits for MTS and 7 digits for IMTS. These briefcases were manufactured in small quantities and cost about $ 3,000 on average (Dlugoš, 2017, p. 14). Figure 4 shows an example of a briefcase mobile phone.

Fig. 4 The briefcase mobile phone

The market for automobile and briefcase phones began to stagnate slowly in the 1970s, and manufacturers were only innovating the looks and small technical details of their devices. Indeed, it was clear that 0-generation networks could not meet the demand for mobile connectivity due to the inefficient use of the available spectrum. At that time, a cellular network prototype had already been developed in AT&T and mobile phone manufacturers were developing their devices in this direction (Gilbert & Stoll, 2014).

2.2. First generation analog mobile devices and networks

The first generation of mobile networks is typically characterized by analogue networks that support voice services. First-generation networks such as AMPS, NMT450, and TACS use FDMA access technology in which one radio channel is reserved for each user. The main disadvantage of these networks is in the use of the analog signal itself, which cannot cover as much area as the digital signal, furthermore it does not allow higher transmission rates and is susceptible to various types of interference.

Analog mobile phones of the first generation were fitted with a rod antenna, most often a half or quarter wave dipole. The mobile phone antenna for the AMPS US network operating at 850 MHz had to be long for the 176 mm half-dipole and 88 mm for the quarter-wave dipole. Such a long rod antenna was impractical and very prone to manual damage, so it had to be replaced later by a spiral antenna. On the other hand, obtaining a half-polar dipole is better than obtaining with spiral or integrated antennas. Another common type of antenna used in analog mobile phones was the sliding antenna, which was a compromise between spiral and rod antennas. In the retracted position, it had a comparable gain to the spiral, and if the signal quality was insufficient for the users, it had the possibility to extend the antenna and obtain parameters comparable to that of a whip antenna. The retractable, also telescopic antenna, was very mechanically stressed and was therefore a frequent source of disturbances (Krásenský & Klapka, 2010).

DynaTAC a ďalšie mobilné zariadenia vyrobené v 80. a 90. rokoch boli vybavené nikel-kadmiovými batériami, ktoré mali hlavnú nevýhodu v ich hmotnosti a veľkosti. Výhody tohto typu článku boli hlavne schopnosť nabíjať sa pri vyššom prúde, čo skrátilo čas, počas ktorého sa batéria nabila, a odolnosť voči nízkym teplotám, pri ktorých nestratila svoju kapacitu kvôli teplote. Jednou z hlavných nevýhod tejto batérie je jej pamäťový efekt, ktorý postupom času znižuje plnú kapacitu batérie, až kým nie je potrebné ju vymeniť. Nikel-kadmiové batérie nainštalované v prvých mobilných telefónoch mali problém s prehrievaním starších batérií počas nabíjania, takže počas životnosti mobilného telefónu bolo bežné batériu niekoľkokrát vymeniť (Krásenský & Skopal, 2008).

In 1973, Martin Cooper led Motorola's engineer team to create the first mobile phone prototype. It was not officially introduced until 1984 due to the ongoing construction of the AMPS network infrastructure. The DynaTAC series was the first series of mobile phones capable of working on the AMPS network. DynaTAC 8000X was the first phone in this series with a height of 25 centimeters and a weight of less than 800 g, was fitted with the same type of battery as those used in briefcases, but thanks to more advanced and less energy-intensive circuits, this battery was several times smaller. The charging time was 10 hours and it was possible to call for 30 minutes. It was fitted with a one-line seven-digit LED display that displayed the dialed number. At the time of its entry into the market, the purchase price was $ 3,995, which is about $ 10,000 compared to today's prices, so this device was a symbol of luxury and wealth. Figure 5 shows a 1st generation mobile phone.

Fig. 5 The first generation of mobile phone DybaTAC 8000x

The DynaTAC 8000X allows you to store up to 30 numbers on internal ROM memory. As one of the first phones to have a device lock feature, it ensured that it was only after entering a three-digit code to receive a call or dial a number (Lacko, 2014).

If Motorola dominated the US mobile phone market, in Europe it was MOBIRO, later known as Nokia. The company introduced several analog mobile devices working on the NMT450 network, such as the MOBIRO Senator, which has been on sale since 1982. In 1985, the company introduced the device as MOBIRO Talkman. This phone, weighing 4.5 kilograms, was not quite pocket-sized, but featured a very advanced technology. In 1987, the MOBIRO Cityman 900 was introduced, reminiscent of the Motorola MicroTAC 9800X, in terms of functionality and functionality in all aspects, just in adapting to the NMT900 network (IOS Developer Library, 2012).

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2.3. Second generation network (2G) and GSM

2G stands for 2nd Generation Wireless Phone Technology. 2G services are often referred to as Personal Communications Service (PCS) in the US.

Examples of standards that use 2G networks are:

- GSM – A European system that is used almost worldwide,
- IS-136 or D-AMPS – used in America
- IS-95 or cdmaOne – used in America and some Asian countries.

Second generation networks differ from their predecessors primarily in their full support for digital communications. Initially, these systems carried exclusively voice, but subsequently data services were added. Compared to the first-generation system, the second-generation networks have, in particular, higher network capacity, digital modulation, which has dramatically improved call quality and, last but not least, the implementation of digital coding and improved eavesdropping resistance. Second-generation systems already use the FDMA/TDMA access technique, which allows multiple users to share a single channel, with each subscriber being separated by a so-called "single channel" approach „timeslots". As the first GSM network was established in 1992 German D2. The result of this development is a safer system, allowing automatic localization, automatic call transfer. A new option was also the transfer of data with a basic rate of 9.6 kbps. The dimensions of infrastructure and terminal equipment have been several times smaller than in the previous generation, and the weight and energy consumption of terminal equipment has also been reduced (Meier, 2012).

2.4. Global System for Mobile Communication - GSM

The development of GSM, which belongs to the second generation of mobile networks, began in 1982, when the Conference of European Post and Telecommunications Administration - CEPT (Group of European Posts and Telegraphs) formed a research group Groupe Special Mobile (the first name for GSM). The Group conducted a study and subsequent development of the trans-European public cellular system in the 900 MHz frequency band. The criteria for the required system were: good subjective speech quality, low end-user and service pricing, international roaming support, mini-handheld end-user capability, enhanced service support (SMS, regional news, etc.). The chronological sequence of GSM development is shown in Table 1

Table 1. The chronological development of GSM

Year	Event
1986	The GSM Development Group was established
1987	basic proposals were set for a separate network
1989	the GSM system was introduced at the conference of the European Telecommunications Standardization Institute ETSI
1991	the first GSM test network called Telekom 91 started operation

Therefore, European mobile phone manufacturers have redirected their evolution towards digital GSM mobile phones. (IOS Developer Library, 2012).

According to the initial specifications, the GSM network should support the following specifications:

- quality transmission of human speech,
- Digital ISDN compatible network
- maximizing network capacity in the frequency band,
- international compatibility and roaming support,
- support of modern services - ISDN,
- low cost of mobile stations and services
- the possibility of minimizing mobile devices,
- minimizing power consumption - battery power.

The cooperation of 26 European telecommunications companies has slowed this development considerably. The demand for GSM-based operating resources has become urgent, and the solution was to divide the standardization process into stages that leave us a legacy today in the form of the three phases of GSM development. These are phases 1, 2 and 2+.

In the first phase, the GSM system provided basic services such as voice transmission, related call barring and call forwarding, voicemail and international roaming. An entirely new feature was the introduction of the SMS service, which was originally intended to transmit messages along signaling routes for the purpose of managing telephone traffic. Therefore, it was necessary to limit the message length to 128 bytes in order to seal the message into a dedicated signaling message space. Later, the size of the SMS was increased to 160 7-bit characters. In 1991, the addition of new services was stopped to allow operators to adapt the space of their existing network to requirements.

In early 1994, the second phase of GSM was introduced, in which the main and key data transfer service was added. This was limited to 9.6 kbps. This phase also brought in particular ancillary services, such as holding a call or informing the user of the next waiting on the line. These specifications were suspended in 1995.

The last phase 2+ was introduced in 1996 and brought a doubling of the number of phone calls on one channel. However, the main improvements were in core services. With the increasing number of GSM network options such as Internet browsing, it became clear that a 9.6 kbps bandwidth limitation would not be sufficient for the data channel. Therefore, the HSCSD (High Speed Circuit Switched Data) method was introduced, which allowed the combination of up to eight time slots. That is, the transfer rate can be increased to 76.8 kbps for a single channel, but in practice the transfer rate is limited to 64 kbps, which is the maximum ISDN channel rate. SIM card services have also recently been expanded (Meier, 2012).

2.5. Generation 2,5 (2,5G)

The 2.5 generation is not a symbol of major breakthroughs, as was the case with 2G. The existing network was primarily focused on voice transmission and related voice services. Circuit switching technology has proven to be an insufficient standard for data transmission in practice, and development has therefore focused on the implementation of packet switching technologies.

The two most important networks are:

- General Packet Radio Service - GPRS
- Enhanced data rates for GSM Evolitation – EDGE.

These networks allow faster data transfer and serve as an intermediate stage for 3rd generation.

Until the advent of GPRS technology, mobile data was transmitted similarly to voice data, either with CSD technology or with a newer HSCSD. Mobile operators usually charged the cost of data services by connection time instead of by the amount of data transferred. This changed in 1998, when a new GPRS technology appeared on the market. It now uses packet interconnection to transmit data that can be unconnected or linked. During a linked data transfer, a communication session or temporary connection must be established, and the data is checked to see if it came in the same order as it was transmitted. The opposite is unconnected transmission, which does not check the correctness of the data. The bit rate is not constant, but depends on the signal quality and the number of services used. In total, up to 8 timeslots can be used. In practice, a maximum of 4 timeslots are used for data transmission, so the real data rate is limited to 85.6 kbps (Meier, 2012).

Since its inception, GSM technology has been improved several times with new systems and standards, the number of subscribers has increased and the transmission speed has increased. However, the existing specifications no longer allowed further development towards faster data transfer. The number of timeslots per frame could no longer be increased to match the effort. HSCSD already uses the method of merging individual timeslots, and efficient use of free channels is implemented in GPRS technology. Progress has therefore moved in a different direction, towards a change in modulation (Meier, 2012).

Although the official launch of the GSM network was in Finland in 1991, the first commercially available

GSM mobile phone was manufactured in workshops by the English company Orbitel and was called Orbitel 901. Although this model would be fully digital, its dimensions have increased again compared to analog predecessors. This was due to the size of the newly used digital components such as modulators and digital converters. This model is not only the first GSM mobile phone, but also the first device to receive an SMS message. It was sent in December 1992 (European Commission, 2006). Figure 6 shows the first commercially available GSM phone from Motorola.

Fig. 6 The first commercially available GSM phone

The first GSM phone that could already be stored in the pocket of the trousers was manufactured by Nokia in November 1992, bearing the designation Nokia 1011, thus beginning the era of dominance of the mobile phone market by Nokia. This model had a black and white two-line display and a sliding antenna. With more advanced, less energy-intensive digital chips and a 900mAh battery, this model has an operating time of up to 12 hours (Pittner, 2015). Figure 7 shows the first handheld mobile phone from NOKIA.

Fig. 7 The first handled phone

After the transition to the new millennium, the whole world already knew how strong and prosperous the mobile phone market was. Only the Nokia 3210 and 3310 models, which were in demand due to their practical design, have sold over 300 million units. With increasing competitors, there was nothing else left for the manufacturers but to force the customer to buy with brand new technologies. Table 2 shows the most significant advances in the 2.5 generation of mobile devices after 2000.

Table 2. Functionalities of mobile phone after 2000

Company	Model	Functionalities
IBM	IBM Simon	touchscreen
NOKIA	NOKIA 9000 Comunicator	reading and sending e-mails and faxes; the Internet
Ericsson	Ericsson T36	Bluetooth
Sharp	Sharp J-SH04	integrated camera
Samsung	Samsung SPH-M100	mp3 player
Sharp	Sharp SH251iS	LCD 3D display
Motorola	Motorola Razer V3	tilting display
Nokia	Nokia N92	DVB-H broadcasting

The development of mobile devices after 2000 has progressed by leaps and bounds.

2.6. Third generation devices and networks

Services related to this generation means the ability to transmit voice (phone call) as well as data (downloaded data, e-mails, messages). Japan was the first country to introduce a third generation of mobile phones. In 2005, 40% of mobile phone users in Japan used third-generation mobile phones. The main service used is not video calls, as expected, but music downloads. Third-generation mobile networks are designed for devices such as PDAs and mobile phones.

Unlike the 2nd generation systems, which used the TDMA method for the vast majority, UMTS uses CDMA multiple code multiplexing. It enables voice and data transmission in parallel, supports VoIP, and redefines Quality of Service (QoS) to optimize network utilization. It defines four QoS service quality classes, which are characterized in terms of transmission rate, packet size, transmission priority or transmission delay (Meier, 2012).

The UMTS standard is based on Wideband CDMA (CDMA) broadband system technology, used mainly in countries with developed GSM networks. The transfer rate of this technology can reach 384 kbps. This standard can provide services that require the so-called always connected apps. UMTS is managed by 3GPP, which is also responsible for GSM, GPRS and EDGE standards (Hordějčuk, 2011).

2.7. The origins of applications in mobile phones

The opportunities brought by mobile phones capable of using the UMTS data network, and thus playing online multimedia and efficient use of WWW services, were reflected mainly in the increasing size of displays. While the phone's hardware keypad capable of sliding beneath the display allowed manufacturers to install several inch displays on their devices, these mobile devices were generally wider. The second option was to place the keyboard under the display, which meant an uncompressed width and height of such a device.

In 2007, the Apple iPhone was introduced at Macworld, the first modern phone to completely remove the hardware keyboard and replace it with a 3.5-inch capacitive display. Although this phone worked on the iOS operating system, it did not fully meet the specifications of the "smartphone" because at the time of introducing this device, the user had no opportunity to install third-party applications. However, thanks to Apple's marketing genius, this model has become a very successful device despite GPRS Internet access, limiting the data rate to 56 kbps. Thanks to Iphone, for the first time the user had the opportunity to operate the system with an intuitive graphical interface only by touch.

Competing devices like the Nokia N95 offered better specification, but simplicity seemed more desirable among users than performance (Štalmach, 2013). Figure 8 shows Apple's first iPhone.

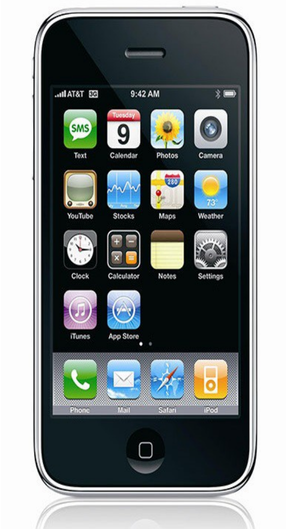

Fig. 8 iPhone by Apple

The development of applications for mobile platforms was still very limited at the time of iOS. Neither BlackBerry OS nor Symbian OS had their own platform for distributing third-party applications. In the case of Symbian OS, the development of GUI (Graphic User Interface) platforms for devices of different manufacturers was an obstacle for developers. Symbian was only the core of the operating system, with each phone manufacturer using its graphical superstructure. Sony Ericsson and Motorola used the UIQ platform, while Nokia used the S60 platform and NTT DoCoMo had its MOAP. This inconsistent solution resulted in the application developed for the Nokia phone not being compatible with a Motorola device, although both phones had the same version of Symbian. With the advent of iOS and the introduction of a new opensource development platform for Apple devices, the number of developers has grown sharply, and Apple introduced its 2008 Appstore, the application distribution platform. The first device to install from a database of more than hundreds of applications was the iPhone 3G (Varga, 2014).

Google immediately responded to this new trend, working with other 33 companies like Samsung and HTC to introduce the Android operating system. It was designed as an open source multiplatform for use on devices from several manufacturers. One week after Android was released, the SDK 1.0 for developers was released. Today, Android is the market leader in operating systems with more than 65% market share, the second is iOS with 30% market share. (Štalmach 2013)

2.8. The fourth generation of mobile networks

This generation focuses primarily on multimedia, ensuring fast data rates for the most demanding multimedia applications, HD mobile TV or online gaming. However, the high-speed bit rate of hundreds of Mbps carries one major drawback, namely the large power consumption, which can be up to ten times greater than HSPA +. Representatives of the 4th generation networks are for example LTE-A, 802.16 or WiMAX mobile.

3. News and current trends in mobile devices

At present, the visual pages of individual mobile devices are very similar, and the ordinary user is not even able to detect technological differences between several manufacturers at the first moment. For a certain amount of money in a specified price range, the user can obtain virtually the same performance device with minor differences caused by different manufacturers. The decisive factor for the user is the workmanship, appearance and operating system. Figure 9 shows a prototype of a first wearable phone.

Fig 9 The first warable phone

In the near future, new and mobile devices will promote larger and larger display areas compared to the phone body. In many types of phones, the hardware button has even been removed, increasing the ratio.

The future trent in imaging technology will undoubtedly be the installation of flexible OLED displays either on conventional phone bodies or on highly bendable platforms that will make it possible to bend to form a bracelet (Tengler, 2018).

Operating systems in mobile phones, be it Android or iOS, still offer only a fraction of the functionality of computer operating systems. This is due to the superfluous implementation of these functions in devices where, due to the small display and the lack of a full keyboard and mouse, it is not possible to carry out a classic office administrative activity. Manufacturers respond to this by supplying special docking stations that, when connected to a phone, redirect the image to a connected monitor, and the user can use a mobile phone as a desktop computer via a graphical interface (Pittner, 2015).

Conclusions

The world of mobile technology is now at a very high level. Thanks to the ingenuity and hard work of mobile phone companies, they are now affecting every sector of the company. Mobile phones have undergone a long and demanding development, the knowledge of which enables us to learn from mistakes and face the new challenges that the mobile phone and device market faces every day.

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