Methodology, Modeling, Traffic Forecasts and Investments needed for the implementation of ERTMS into the Railway Network of Bulgaria

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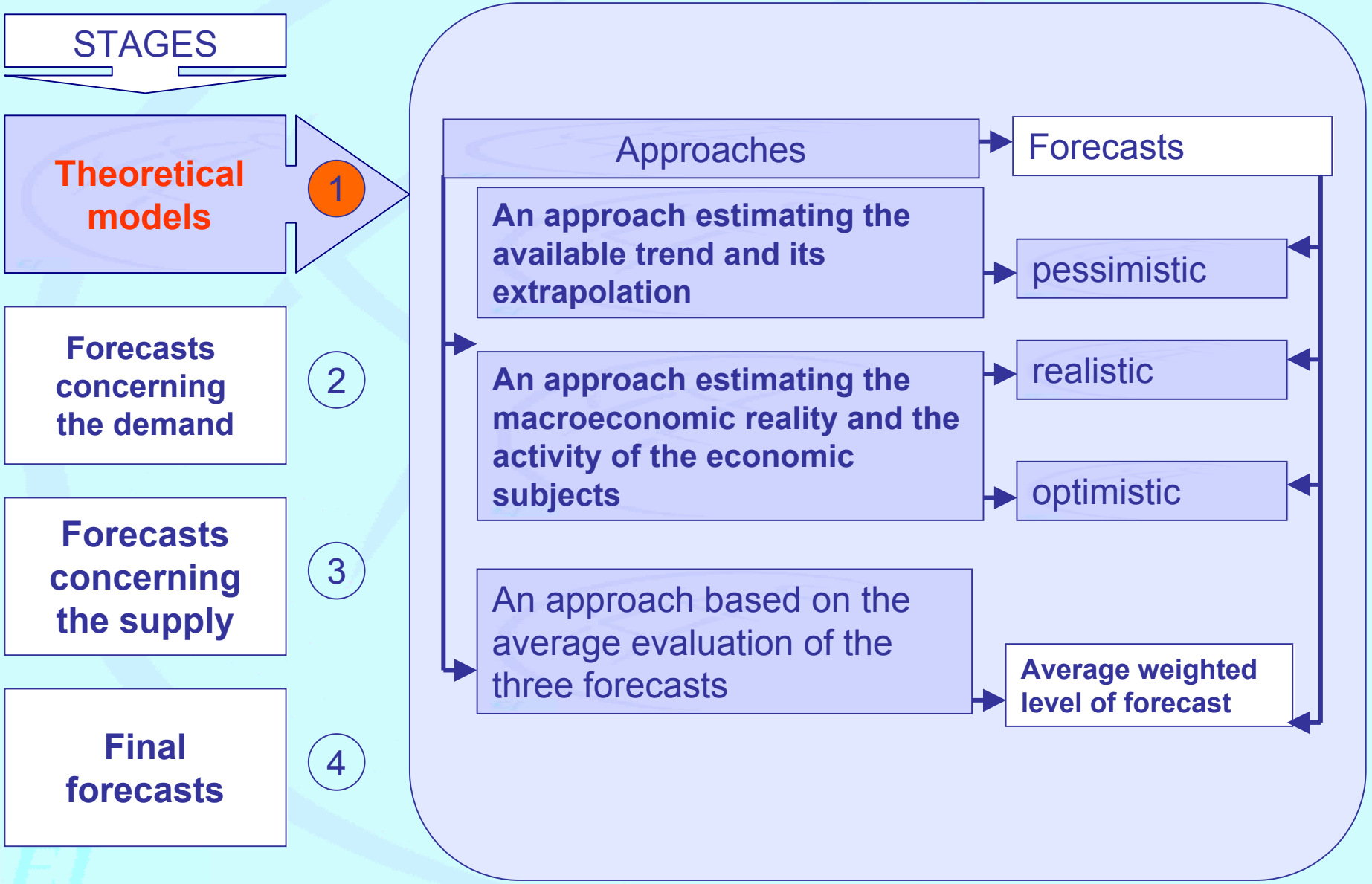
Methodology for forecasting the work and traffic in the railway network of Bulgaria



Methodology for forecasting the work and traffic in the railway network of Bulgaria

STAGES

Theoretical models 1

Forecasting the work and traffic, considering the alternative “Nothing is done.”

Forecasts concerning the demand 2

Forecasting the work and traffic, considering the alternative “implementation of ERTMS/ETCS L1”

Forecasts concerning the supply 3

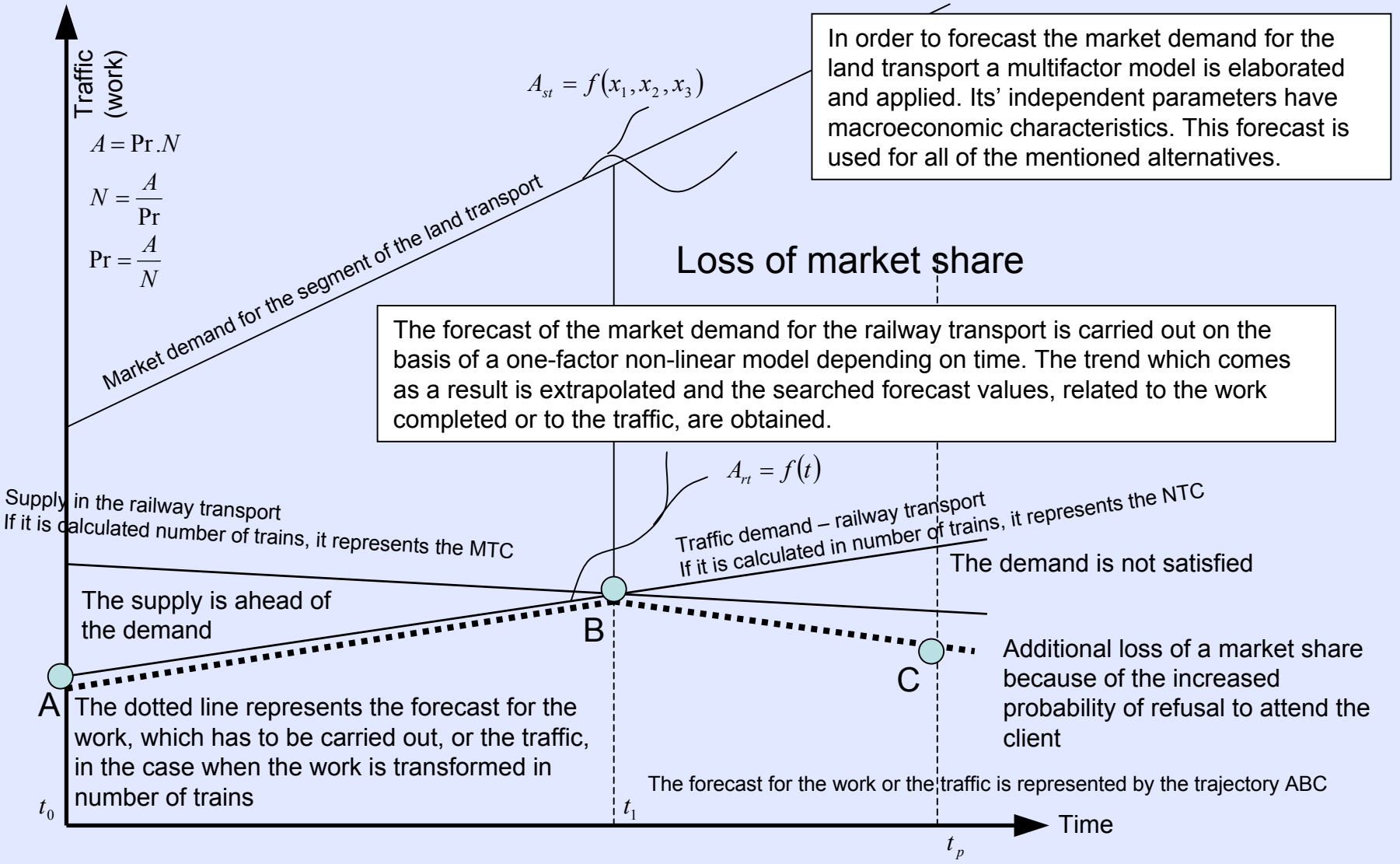
Forecasting the work and traffic, considering the alternative “implementation of ERTMS/ETCS L2”

Final forecasts 4

Choice and realization of the theoretical models

Forecasting the work and traffic, considering the alternative "Nothing is done."

(It is done for each of the approved railway sections and for the whole railway network)



MTC – maximum traffic capacity; NTC – necessary traffic capacity

Typical symbols and explanations related to the alternative “Nothing is done.”

t_0 - Beginning of the forecasted period

t_p - End of the forecasted period

t_1 - Moment of depletion of the MTC

A – Traffic (work) in the beginning of the forecasted period;

B – Traffic (work) in the end of the forecasted period;

C – Traffic (work) when the MTC is depleted. At this point the demand and the supply are equal;

ABC – Trajectory that shows the forecasted traffic (work);

$A_{st} = f(x_1, x_2, x_3)$ - Forecast of the work completed – total for the land transport (automobile and railway)

x_1, x_2, x_3 - Macroeconomic indices

$A_{rt} = f(t)$ - Forecast for the work completed for the railway transport as a function of time

$\Pr = \frac{A}{N}$ - Productivity per train; A - Work carried out (ton.km); N - Number of freight trains (traffic);

$A = \Pr . N$ - Transformation of the number of trains (traffic) into work (tons/km)

$N = \frac{A}{\Pr}$ - Transformation of the work (tons/km) into number of trains (traffic)

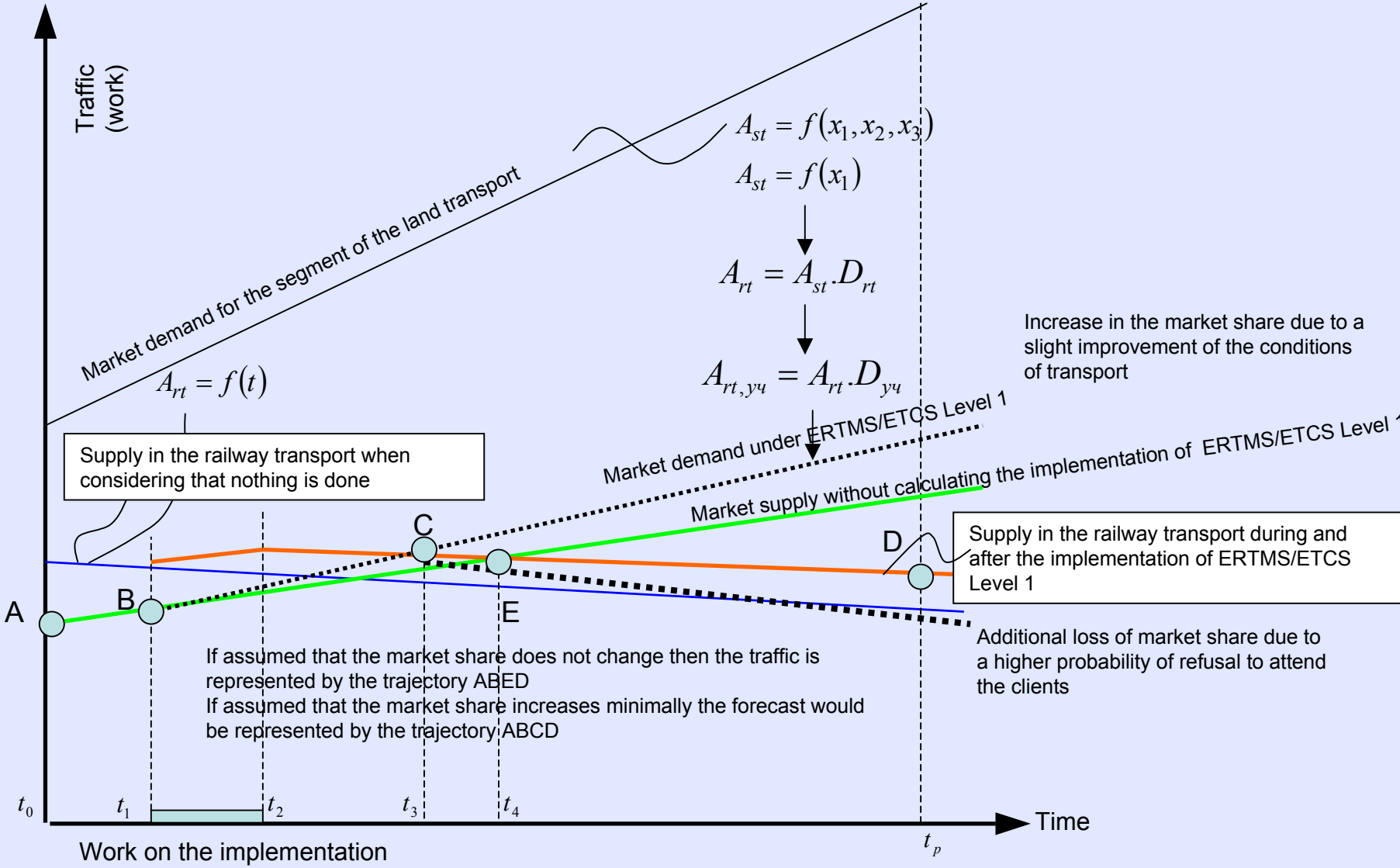
$D_{rt} = \frac{A_{rt}}{A_{st}}$ - Market share of the work, completed by the railway transport;

A_{rt} - Work completed by the railway transport; A_{st} - Work completed by the land transport;;

$A_{st} = A_{rt} + A_{at}$ - Work carried out by the land transport, as a sum of the work completed by the railway transport and the one completed by the automobile transport

Forecasting the work and traffic, considering the alternative “implementation of ERTMS/ETCS L1”

(It is done for each of the approved railway sections and for the whole railway network)



Typical symbols and explanations of the alternative “implementation of ERTMS/ETCS L1”

t_0 - Beginning of the forecasted period

t_p - End of the forecasted period

t_1 - Beginning of the implementation of ERTMS/ETCS L1

t_2 - End of the implementation of ERTMS/ETCS L1

t_3 - Moment of depletion of the MTC considering the forecast of the traffic with an increase of the market share because of the implementation of ERTMS/ETCS L1

t_4 - Moment of depletion of the MTC when rendering account of the forecast of the traffic without an increase of the market share because of the building of ERTMS/ETCS L1. (basic forecast of the demand)

A – Traffic (work) in the beginning of the forecasted period.

B – Traffic (work) in the begging of the building of ERTMS/ETCS L1.

D – Traffic (work) in the end of the forecasted period.

C – Traffic (work) when the MTC is depleted. At this point the supply equals the demand.

E – Traffic (work) when the MTC is depleted. At this point the supply equals the demand.
The forecast for the demand does not report for an increase in the market share. A basic forecast is used.

ABCD – Trajectory, which shows the forecasted traffic (work), when a forecast that assumes an increase in the market share is considered.

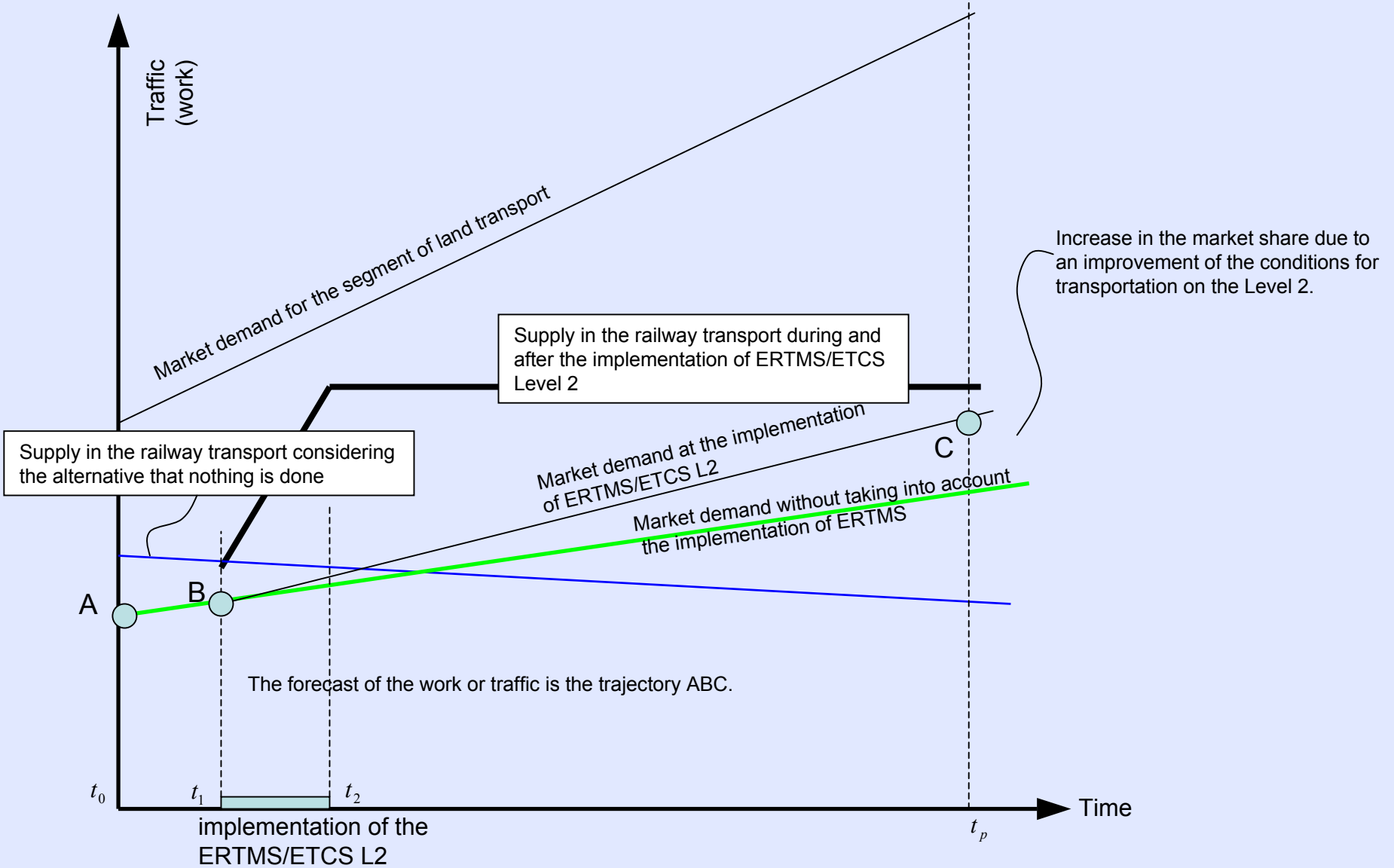
ABED – Trajectory, which shows the forecasted traffic (work) when a basic forecast of demand is considered.

$A_{rt} = f(t)$ - Forecast for the work completed for the railway transport as a function of time – basic forecast.

Parameters, on which the quality and market share of the freight transportations depend on:
- Probability of refusal to transport the clients (depends on the supply and demand - depletion of the MCT;
- Speed of motion (depends on the condition of the railway road and the rolling stock);
- Time for completion of the transport (depends on the speed, the type of the centralizations, and the way of assuring the traffic of the trains and the technological planning of the transportations– train traffic timetable);
-Transport distance (depends on the completion and the capacity of the railway and the automobile transport).

Forecasting the work and traffic, considering the alternative “implementation of ERTMS/ETCS L2”

(It is done for each of the approved railway sections and for the whole railway network)



Typical symbols and explanations of the alternative “implementation of ERTMS/ETCS L2”

t_0 - Beginning of the forecasted period

t_p - End of the forecasted period

t_1 - Beginning of building up of ERTMS/ETCS L2

t_2 - End of building up of ERTMS/ETCS L1

A – Traffic (work) in the beginning of the forecasted period.

B – Traffic (work) in the begging of the building of ERTMS/ETCS L2.

C – Traffic (work) in the end of the forecasted period, assuming the forecast for the demand at ERTMS/ETCS L2. The forecast for the demand with the already built ERTMS/ETCS L2 reports an increase of the market share as a consequence of this fact.

ABC – Trajectory, which shows the forecasted traffic (work) considering a forecast for demand, reporting an increase of the market share with the already build ERTMS/ETCS L2.

AB – Forecast for the work and traffic – basic forecast. $A_{rt} = f(t)$

BC – Forecast for the traffic, having ERTMS/ETCS L2 built.

In this alternative the demand is fully satisfied. There are no limits considering the supply. A possibility for an increase of the market share exists, it is based on the improved quality of the service offered.

Methodology for forecasting the work and traffic in the railway network of Bulgaria

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II. Forecasts related to the market demand.

1. Elaboration of a forecast for the work and traffic in certain railway segments for a defined forecast horizon on the basis of a one-factor regression analysis.

1.1. Forecast models for the freight transportations.

1.2. Forecast models for the passenger transportations.

2. Elaboration of a forecast for the work and traffic of the railway transport based on the macroeconomic indices.

2.1. Elaboration of a forecast for the work and traffic of the land transport based on the macroeconomic indices.

2.1.1. Forecast models for the work of the freight transportations.

2.1.2. Forecast models for the work of the passengers land transport.

2.2. Analysis of the market share pertaining to the railway transport.

2.3. Forecast for the work and traffic of the railway transport based on macroeconomic indices.

2.3.1. Forecast for the freight railway transportations.

2.3.2. Forecast for the passenger railway transportations.

3. Expert forecasts related to other types of transport.

3.1. Combined transportations - “Ro-La” or another type.

3.2. Forecasts for the work and traffic of significant freight clients.

4. Determination of the ratio between the passengers’ and freight traffic

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Freight transportations.
Indices forecasted – work in net (weight) ton-km.

Pessimistic forecast.

The forecast method is extrapolative and is connected to the application of a a one-factor regression analysis with the main factor being time. To obtain the unknown quotients in the chosen mathematical dependencies the method of the lowest squares is applied. For each segment a different relationship is obtained.

Realistic forecast.

The forecast method is extrapolative and is connected to the application of a multifactor regression analysis with the main factors being – chosen macroeconomic indices.

In order to obtain the unknown quotients in the chosen relationships, with which the completed work by the land transport is forecasted, the method of least squares (MLS) is applied.

The realistic forecast is attained on the basis of the market share of the railway transport. It is a measurement that represents an average-weighted value from three possible variants of market shares, evaluated with their corresponding probabilities.

Optimistic forecast.

The forecast method is extrapolative and is related to the application of a multifactor regression analysis with the main factors being – chosen macroeconomic indices.

The optimistic forecast is obtained on the basis of the forecast of the work completed by the land transport and the maximum market share that could belong to the railway transport.

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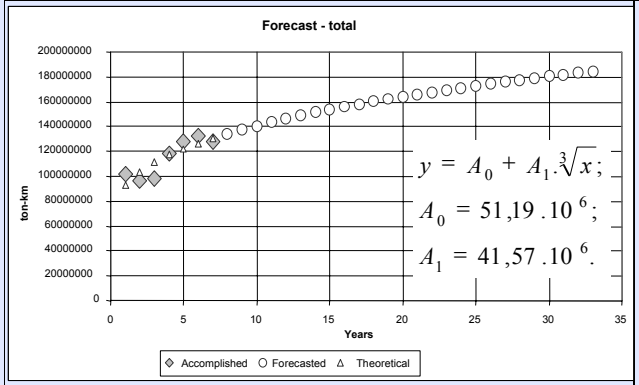
Freight transportations (factor – time)

Example of one railway section

Railway section Kalotina west -Sofia

Graph representation



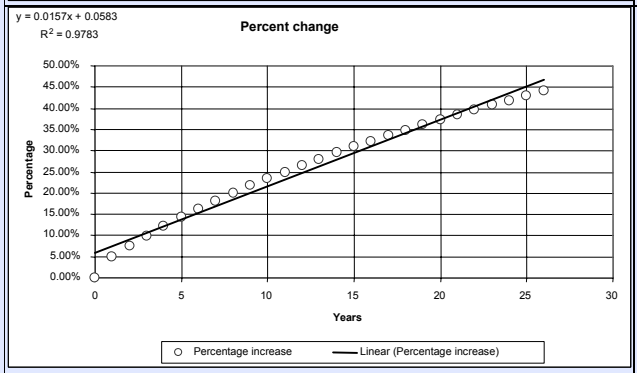


Fig.7

Description of the forecast model

y - work, carried out in the railway section, measured in ton-km

x - time

$y = A_0 + A_1.\sqrt[3]{x}$ - forecast dependency

$A_0 = 51{,}19.10^6$ and

$A_1 = 41{,}57.10^6$ - quotients of the model

$x = 1,2,3,.....,33$

$x = 1$ corresponds to the year 2000

$x = 33$ corresponds to the year 2032, etc.

$z = P_1.t + P_0$ - percent change in dependence of time

$t = 0,1,2,.....,26;$

t = 0 corresponds to the year 2006 and t=26, to the year 2032 ;

$R^2 = 0.9783$ - quotient of determination

$P_0 = 0.0583$ - intercept

$P_1 = 0.0157$ - slope of the linear equation

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Passenger transportations (factor-time)
Pessimistic forecast

General forecast for the railway network

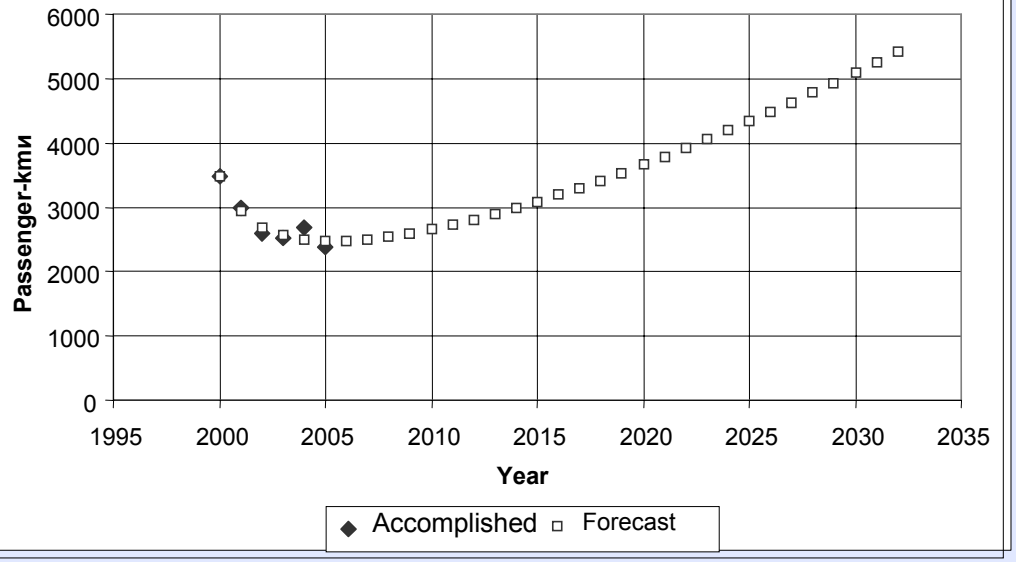
$$Y = C_0 + \frac{C_1}{t^{1/4}} + C_2 . t^{1,4}$$

$C_0 = -296,77;$

$C_1 = 3743,48;$

$C_2 = 31,07.$

Passenger-km accomplished by the railway transport – forecast in dependence of time



The general forecast is laid upon the structure of the railway network and forecasts for the separate railway sections are obtained

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Forecasts based on macroeconomic indices

-Selection of the macroeconomic indices.
-Selection of the macroeconomic indices, which have a major influence on the completed work by the land transport
-Elaboration of a multifactor forecast model, in which the work completed by the land transport depends on the macroeconomic indices that have been chosen
-Elaboration of non-linear forecasts for each one of the macroeconomic indices, in dependence of time
-Determination and analysis of the market share of the railway transport.
-Final forecast of the work completed by the railway transport for a determined forecast horizon.

Forecasts of the following type:
- Work completed by the land transport (net (weight) in ton-km) depending on the chosen macroeconomic indices;
- Values of the macroeconomic indices in dependence of time;
- Work completed by the railway transport in dependence of the market share, having considered different alternatives (pessimistic, optimistic and realistic)

Description of the independent variables – freight transport	
Independent variables	
X1L or X1d thousand BGN or U.S. dollars	The gross domestic product (GDP). A measurement of the market value showing the final result of the production activity in the economy over a certain period. Measured in thousand BGN or U.S. dollars.
X2 thousand U.S. dollars	The gross domestic product per capita (of the population) is a measurement of the level of the GDP, it shows the amount of the GDP commensurate with the number of the population in a given country.
X3 thousand BGN	Index – Money out of the banking system. It is identical to the index Money in circulation of the European Central Bank.
X4 thousand BGN	The index "Bulgarian national standard, agricultural sector", represents the gross added value imposed by the producers, classified in the agricultural sector.
X5 thousand BGN	The index "Bulgarian national standard, industrial sector", represents the gross added value imposed by the producers, classified in the industrial sector.
X6 thousand BGN	The index "Bulgarian national standard, services sector", represents the gross added value imposed by the producers, classified in the services sector.
X7 thousand BGN	Export of goods and services – it's the sum of the value of the exported goods according to the prices FO on statistics from the exterior trade and the export of services (credit) – according to statistics of the payment balance.
X8 thousand BGN	Import of goods and services – it's the sum of the value of imported goods according to prices from FOB from statistics of the exterior trade and the importation of services (debit) according to statistics of the payment balance.
X9 thousand BGN	M2 = M1 + QUASIMONEY
X10 Million euros	The direct investment is a category in the international investments, it which a resident of a given economy obtains a long-term interest (at least 10 % of the shared capital or the right to vote) in a societies, which is found in another economy.
X11 % of the GDP	Investments as a % of the GDP
Forecasted index (dependent variable)	
Y Million ton-km	The total sum of completed ton-km by the land transport (automobile and railway).

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Multifactor model for forecasting the completed work by the land transport – freight transportations

Model

$$Y = A_0 + A_1.X_1 + A_2.X_9 + A_3.X_{10} + \varepsilon$$

$A_0 = 0;$

$A_1 = 0.757739587;$

$A_2 = -0.006853;$

$A_3 = 69.741507$

Correlation quotient		
Indices	Land transport	
	Transported freight	Achieved work
	Thousand tons	Million ton-km
		Y
X1 in thousand BGN	0.08860863	0.50933719
X1 in thousand $	0.53851685	0.87212926
X3	0.2998588	0.69919999
X9	0.36145117	0.76188405
X10	0.29437774	0.64119701
X11	0.17750225	0.57561575

Forecasted index (dependent variable)	
Y	The total sum of completed ton-km by the land transport (automobile and railway).
Independent variables	
X1 thousand U.S. dollars	The gross domestic product (GDP). A measurement of the market value showing the final result of the production activity in the economy related to a certain period. Measured in thousand BGN or U.S. dollars.
X9 thousand BGN	M2 = M1 + QUASIMONEY
X10 million euros	The direct investment is a category in the international investments, in which a resident of a given economy obtains a long-term interest (at least 10 % of the shared capital or the right to vote) in a societies, which is found in another economy.

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Forecasting the chosen macroeconomic indices

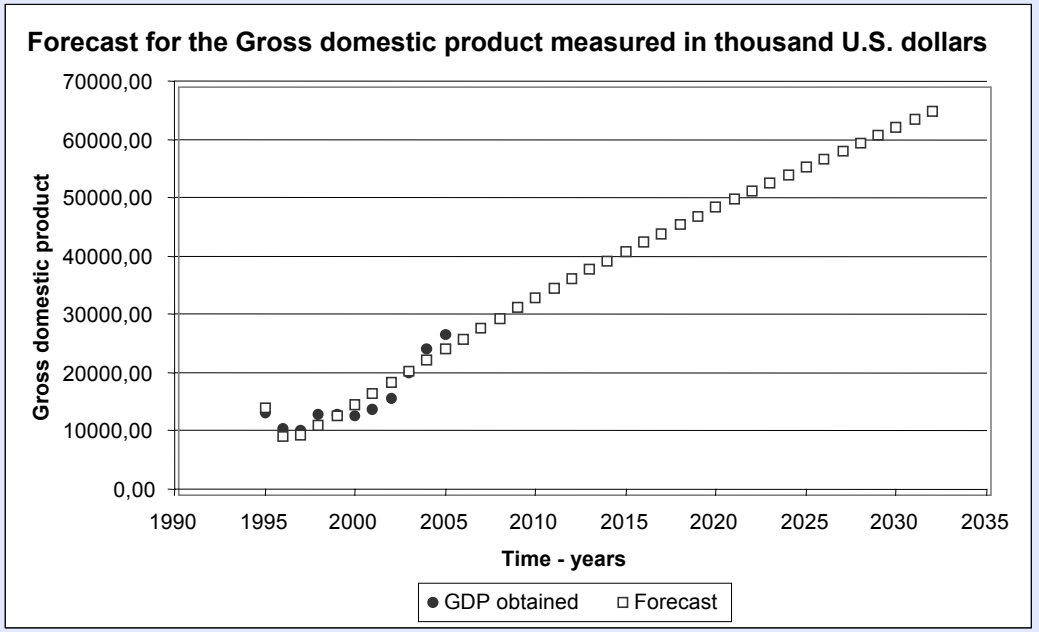
Forecast model of the GDP (thousand U.S. dollars)

$$X_1 = C_0 + C_1 t^{2/3} + \frac{C_2}{t}$$

$C_0 = -10098.231;$

$C_1 = 6574{,}9079;$

$C_2 = 17365{,}3360.$



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4. **Final forecasts**

Forecasting the chosen macroeconomic indices

Forecast model of

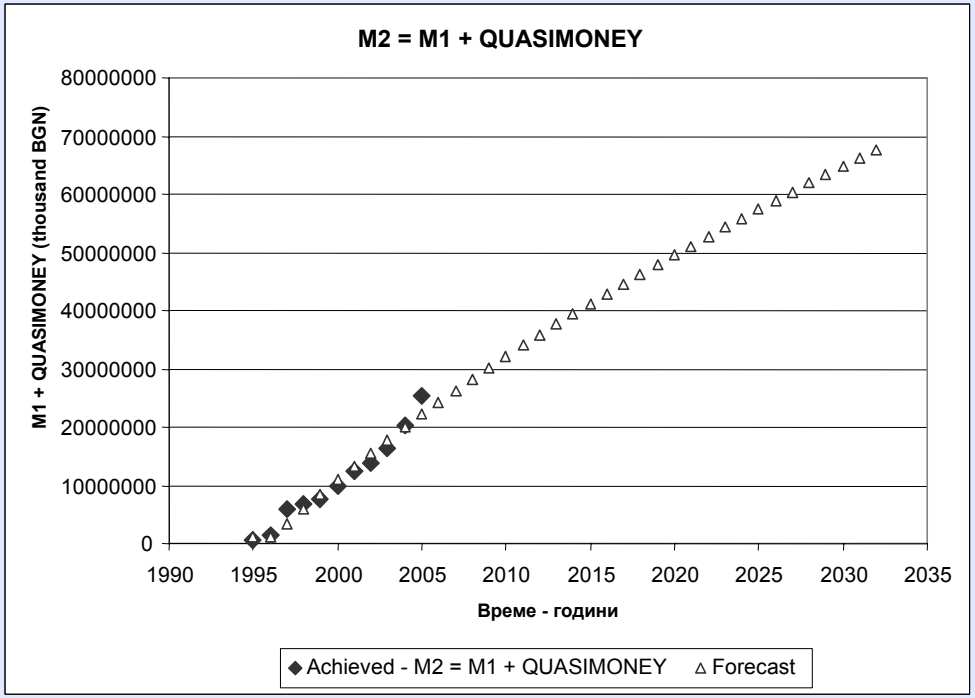
M2 = M1 + QUASIMONEY (thousand BGN)

$$X_9 = C_0 + C_1.t^{2/3} + \frac{C_2}{t}$$

$C_0 = -14.3315.10^6;$

$C_1 = 7.2352.10^6;$

$C_2 = 8.1662.10^6.$



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Forecasting the chosen macroeconomic indices

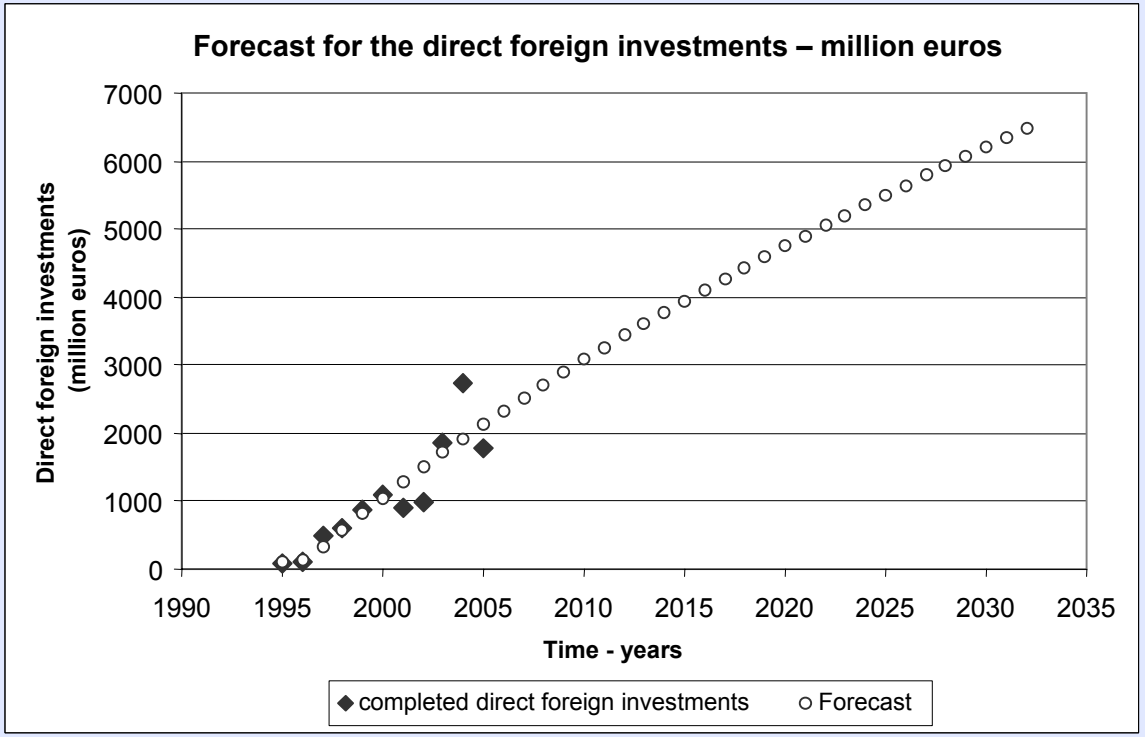
Forecast model of the direct foreign investments (million euros)

$$X_{10} = C_0 + C_1 t^{2/3} + \frac{C_2}{t}$$

$C_0 = -1383.6558;$

$C_1 = 694.8327;$

$C_2 = 807.6791.$



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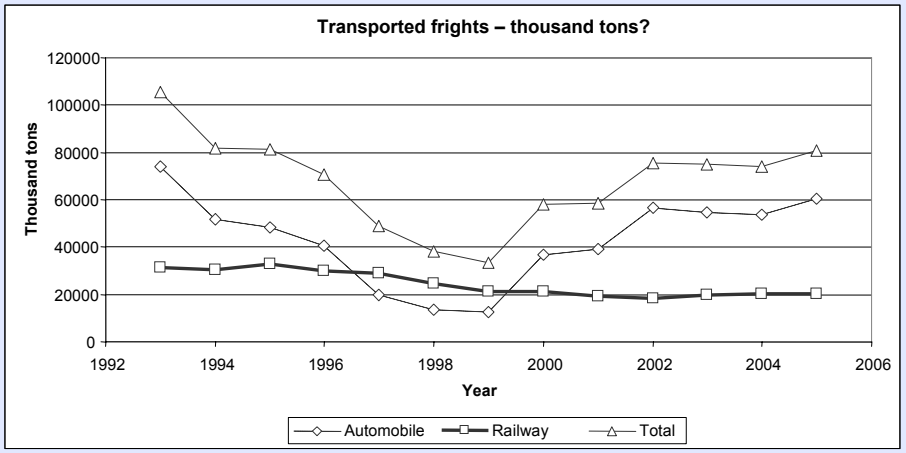
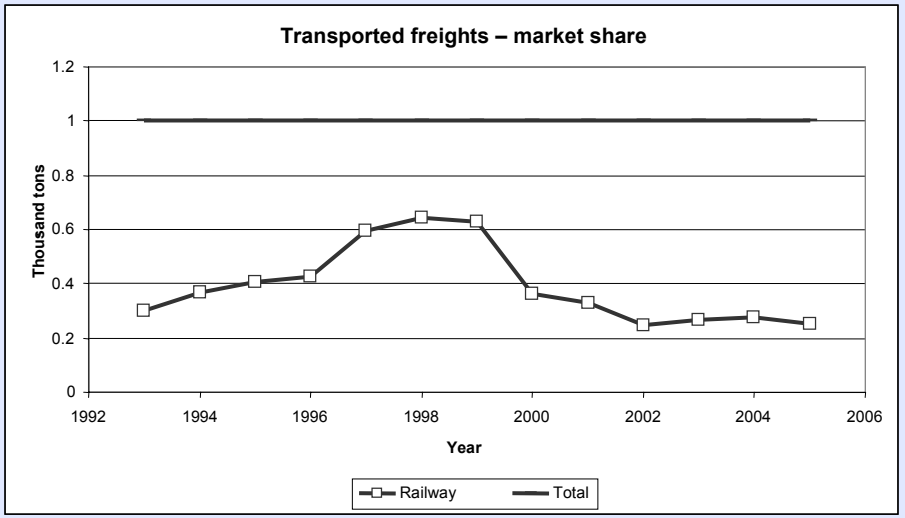
Analysis of the market share of the railway and the automobile transport (transported freights)





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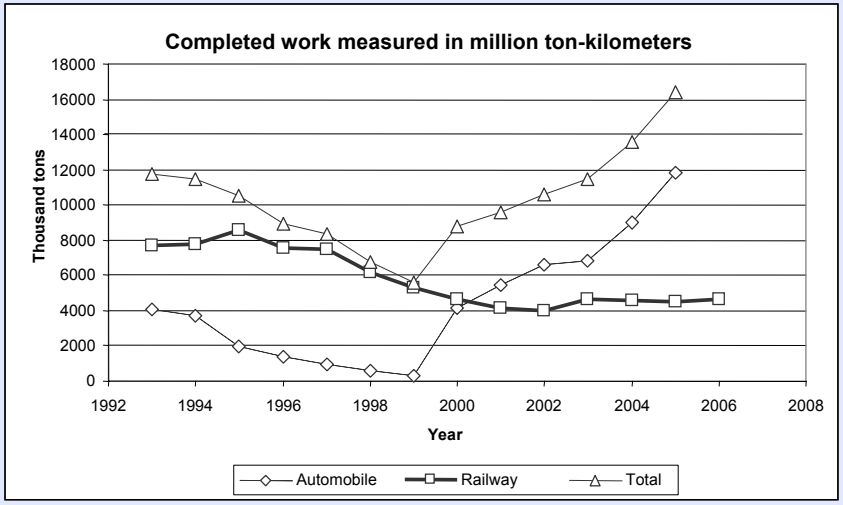
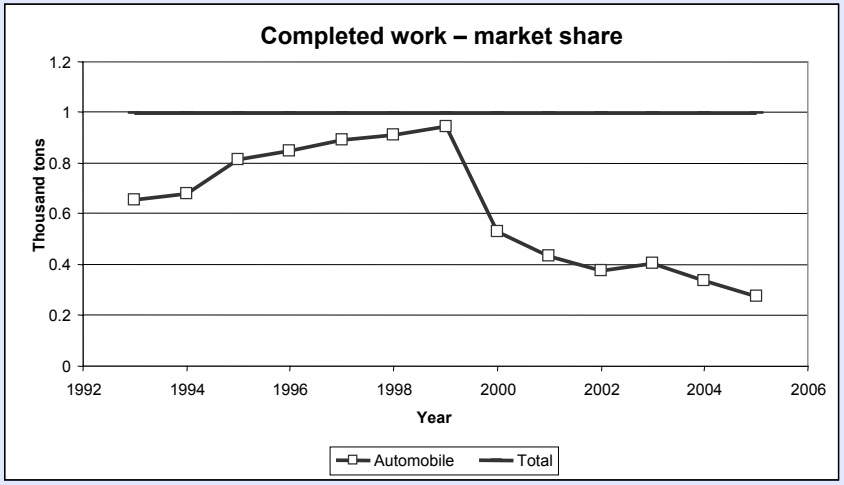
Analysis of the market shares that belong to the railway and automobile transport (transported freights)





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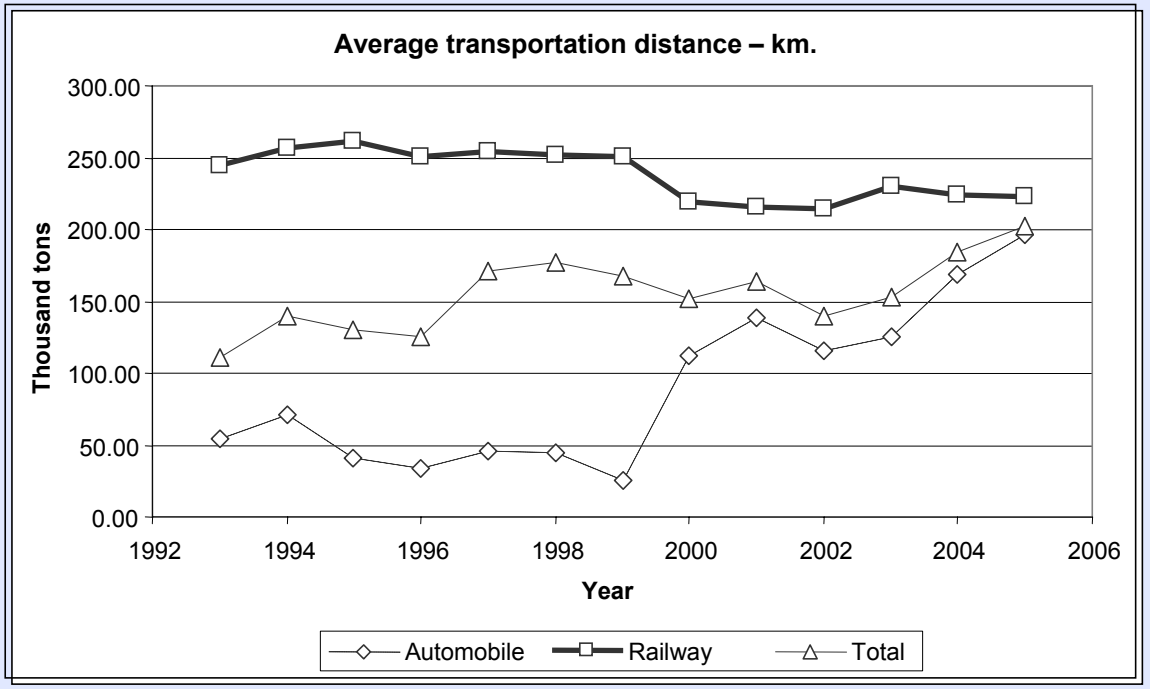

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Forecasts – freight transportations

Optimistic (high level of forecast), which is based on a 33% market share of the total work completed by the land transport;

realistic, which represents an average-weighted measurement, comprised of three possible alternatives of the market shares, evaluated with the corresponding probabilities

pessimistic (low level of forecast) – this is the forecast, based on the relationship of the work completed by the railway transport in dependence of the factor time. It is pessimistic because it maintains the trend in the change of the market share that belongs to the railway transport. In this approach the influence of the quality of the transport service on the market share cannot be taken into account.

Description of the independent variables – passenger transportations	
Independent variables	
X1L or X1d thousand BGN or U.S. dollars	The gross domestic product (GDP). A measurement of the market value showing the final result of the production activity in the economy related to a certain period. Measured in thousand BGN or U.S. dollars.
X2 thousand U.S. dollars	The gross domestic product per capita (of the population) is a measurement of the level of the GDP, it shows the amount of the GDP commensurate with the number of the population in a given country.
X3 thousand BGN	Index – Money out of the banking system. It is identical to the index Money in circulation of the European Central Bank.
X4 Nominal BGN.	The total income is a summary measurement of the monetary and the natural income (that has been given a value) – that the households have received in a given period. The natural income includes the income of the alimentary products, non-alimentary goods, livestock and others, manufactured by the households or received without retribution from relatives, economic organizations and other sources.
X5 Nominal BGN	Total cost, transport, average per person
X6 Nominal BGN	The gross wage is the remuneration that the person receives in exchange for the work he has done before the corresponding deductions are realized – the obligatory and voluntary payments for social and health security, the different taxes – as debts the hired worker has to pay.
X7 number	The constant population , which includes: Constant available population (people who live permanently in the country, respectively also considering that until the given moment (the day of the census or the end of the year) they haven't left the country), and the temporarily non-present people (people who live permanently in the country but in the given moment are absent – for less that a year).
X8 %	Percent ratio of the number of registered unemployed people, in relation to the economically active population, considering the information from the census, obtained by the National Statistics Institute.
Forecasted index (dependent variable)	
Y	Completed ton-km totally by the land transport (automobile and railway)

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Passenger transportations.
Forecasted index – achieved passenger-km.

Pessimistic forecast.

The forecast method is extrapolative and is connected to the application of a a one-factor regression analysis with the main factor being time. To obtain the unknown quotients in the chosen mathematical dependencies the method of least squares is applied. A forecast dependency is obtained related to the whole railway network. After the forecast is being laid upon the structure of the railway network we obtain as a result the forecasts for the separate railway sections.

Realistic forecast.

The forecast method is extrapolative and is connected to the application of a multifactor regression analysis with the main factors being – chosen macroeconomic indices.

In order to obtain the unknown quotients in the chosen relationships, with which the completed work by the land transport is forecasted, the method of least squares (MLS) is applied.

The realistic forecast is obtained on the basis of the forecast for completed work by the land transport and a constant market share of the railway transport.

Optimistic forecast.

The forecast method is extrapolative and is related to the application of a multifactor regression analysis with the main factors being – chosen macroeconomic indices.

The optimistic forecast is obtained on the basis of the forecast of the work completed by the land transport and the increasing market share that could belong to the railway transport.

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Multifactor model for forecasting the work completed by the land transport – passenger transportations

$$Y = A_0 + A_1.X_2 + A_2.X_5 + A_3.X_8 + \varepsilon$$

$A_0 = 21600{,}3745;$

$A_1 = -6{,}82679;$

$A_2 = 179{,}0042;$

$A_3 = -290{,}6783.$

Indices	Correlation quotient Land transport	
	Passengers transported (thousands)	Passenger-km (millions)
X2 thousand $	-0,884821	-0,799985
X5 nominal.BGN	-0,875150	-0,736833
X8 %	0,894984	0,780800

Forecasted index (dependent variable)	
Y	Completed ton-km totally by the land transport (automobile and railway).
Independent variables	
X2 thousand U.S. dollars	The gross domestic product per capita (of the population) is a measurement of the level of the GDP, it shows the amount of the GDP commensurate with the number of the population in a given country.
X5 Nominal BGN	Total cost, transport, average per person
X8 %	Percent ratio of the number of registered unemployed people, in relation to the economically active population, considering the information from the census, obtained by the National Statistics Institute.

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Forecast of the chosen macroeconomic indices

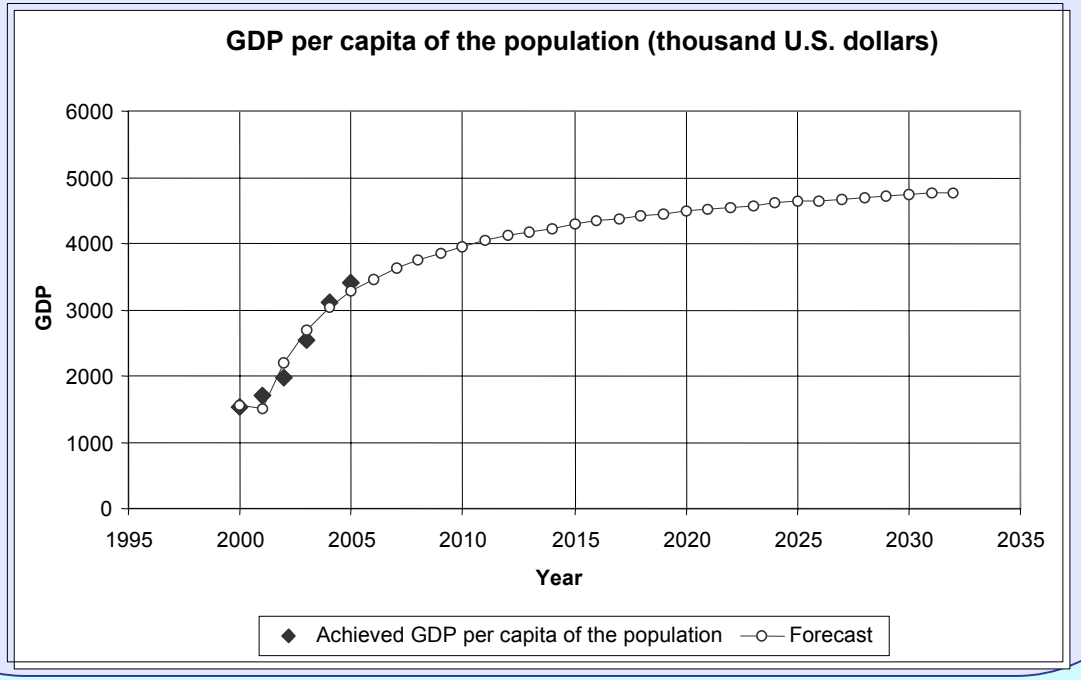
Forecast model of the GDP per capita of the population (thousand U.S. dollars)

$$X_2 = C_0 + \frac{C_1}{\sqrt{t}} + \frac{C_2}{e^{t^{1,85}}}$$

$C_0 = 5883{,}547453;$

$C_1 = -6389{,}737403;$

$C_2 = 5604{,}399132.$



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Forecast of the chosen macroeconomic indices

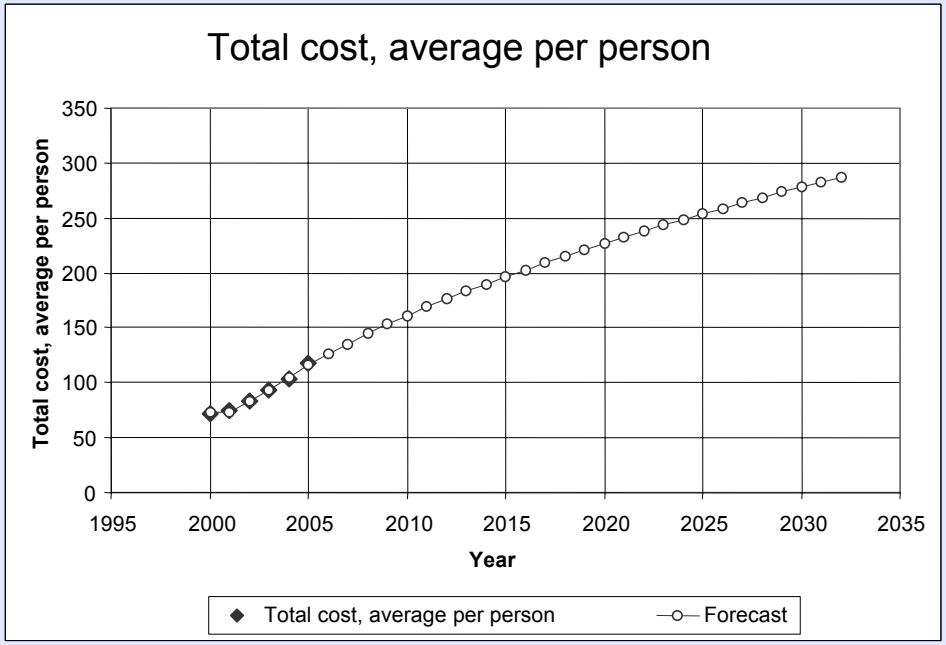
Forecast model of:
Total cost, transport, average per person (nominal BGN)

$$X_5 = C_0 + C_1.\sqrt{t} + \frac{C_2}{e^t}$$

$C_0 = -11{,}745519;$

$C_1 = 52{,}0455189;$

$C_2 = 87{,}3771213.$



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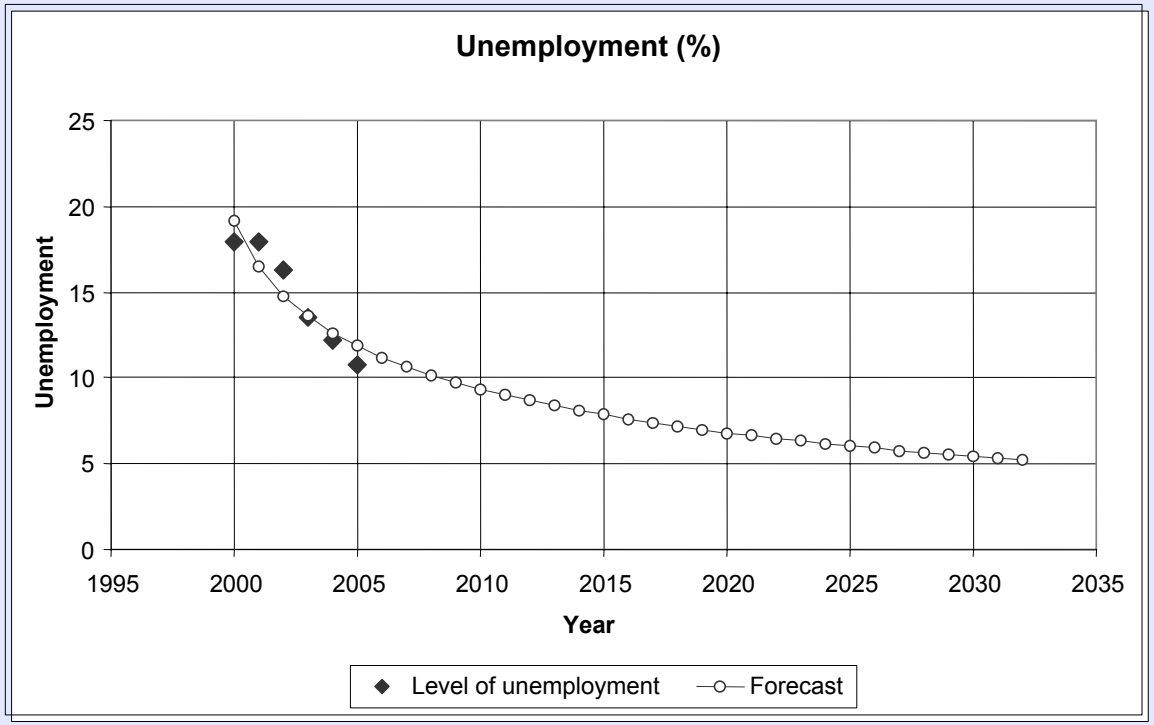
Forecast model of the level of unemployment (%)



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Multifactor model for forecasting the work completed by the land transport

$$Y = A_0 + A_1.X_2 + A_2.X_5 + A_3.X_8 + \varepsilon$$

$A_0 = 21600{,}3745;$
$A_1 = -6{,}82679;$
$A_2 = 179{,}0042;$
$A_3 = -290{,}6783.$

$$X_2 = C_0 + \frac{C_1}{\sqrt{t}} + \frac{C_2}{e^{t^{1,85}}}$$

$C_0 = 5883{,}547453;$
$C_1 = -6389{,}737403;$
$C_2 = 5604{,}399132.$

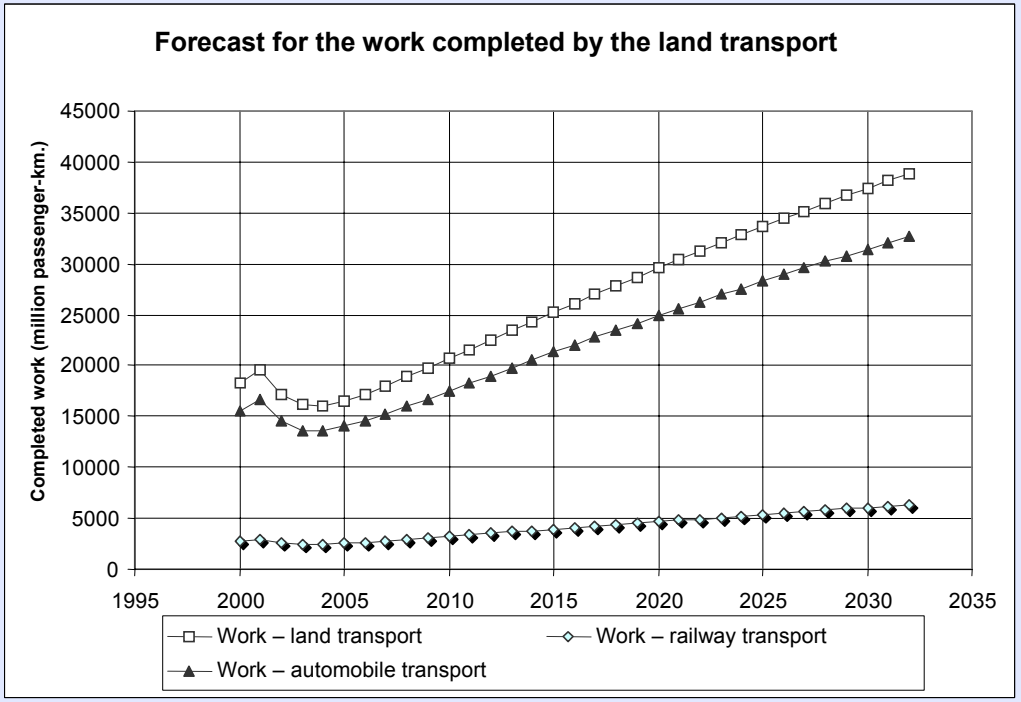
$$X_5 = C_0 + C_1.\sqrt{t} + \frac{C_2}{e^t}$$

$C_0 = -11{,}745519;$
$C_1 = 52{,}0455189;$
$C_2 = 87{,}3771213.$

$$.X_8 = \frac{C_0}{e^{C_1.t^{1/3}}}$$

$C_0 = 34{,}59336258;$
$C_1 = 0{,}589038482.$

Representation of the forecast as a linear function in relation to time



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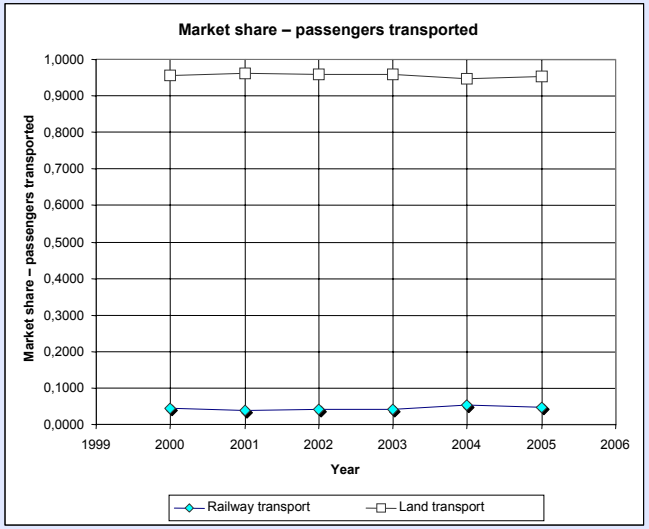
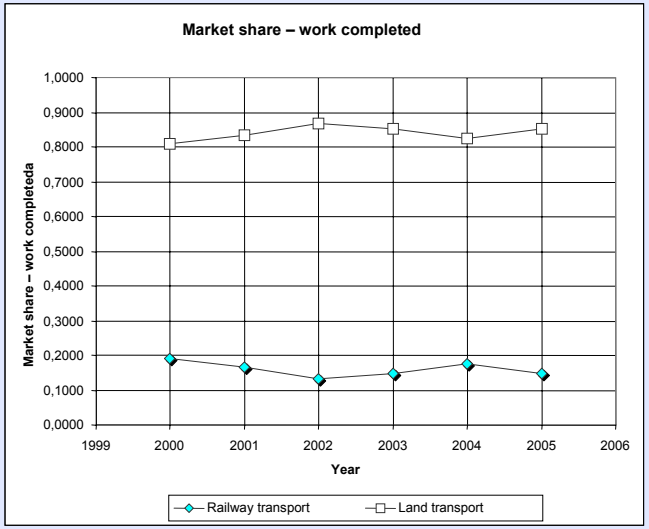
Analysis of the market shares that belong to the railway and automobile transport (passengers transported)





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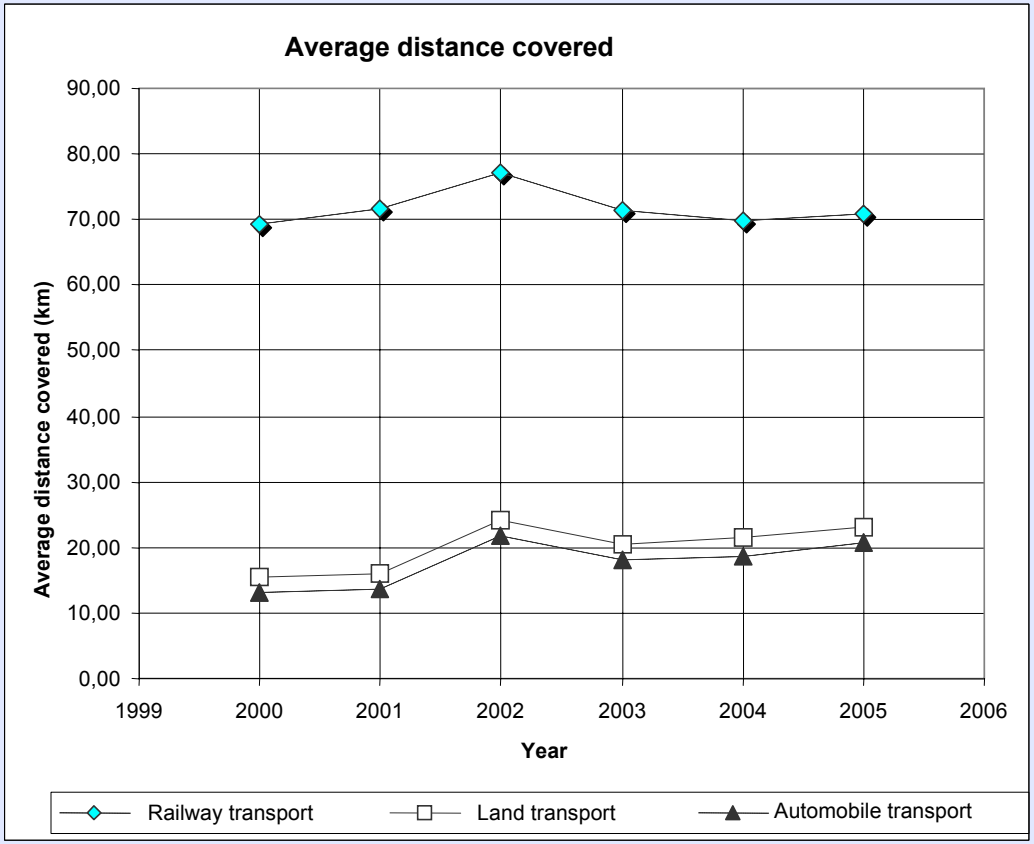

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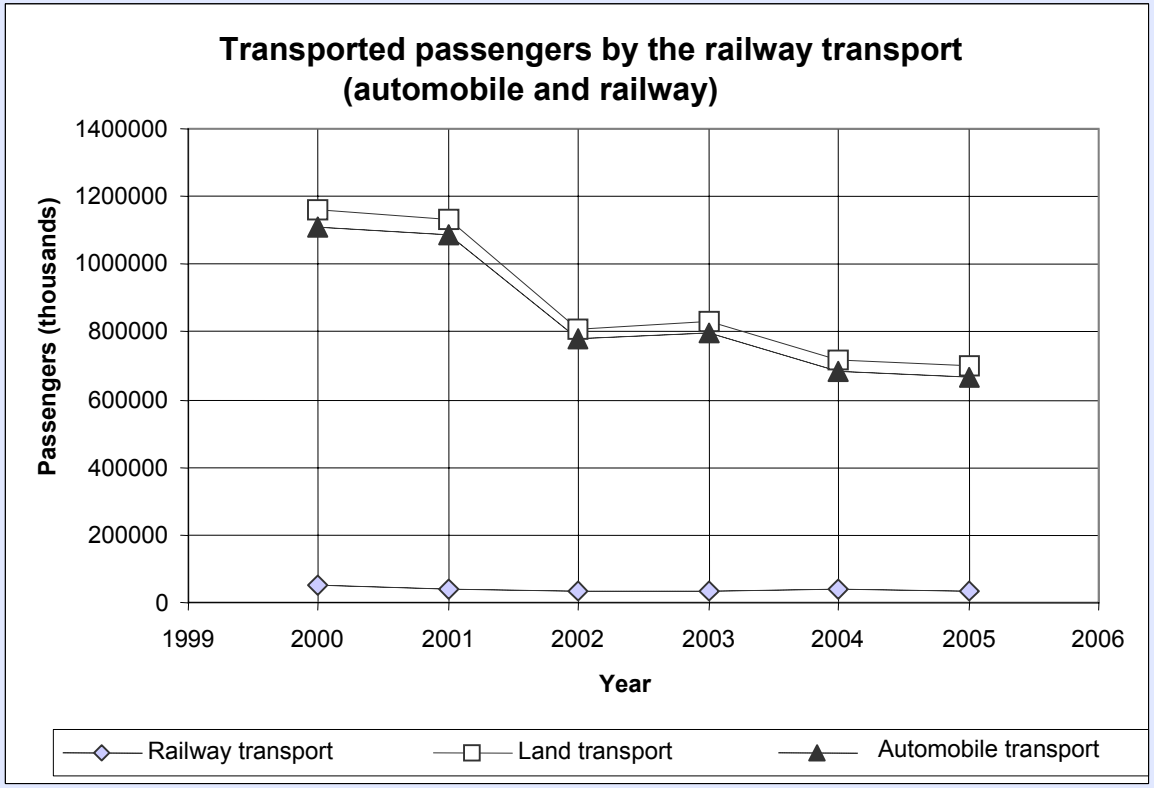

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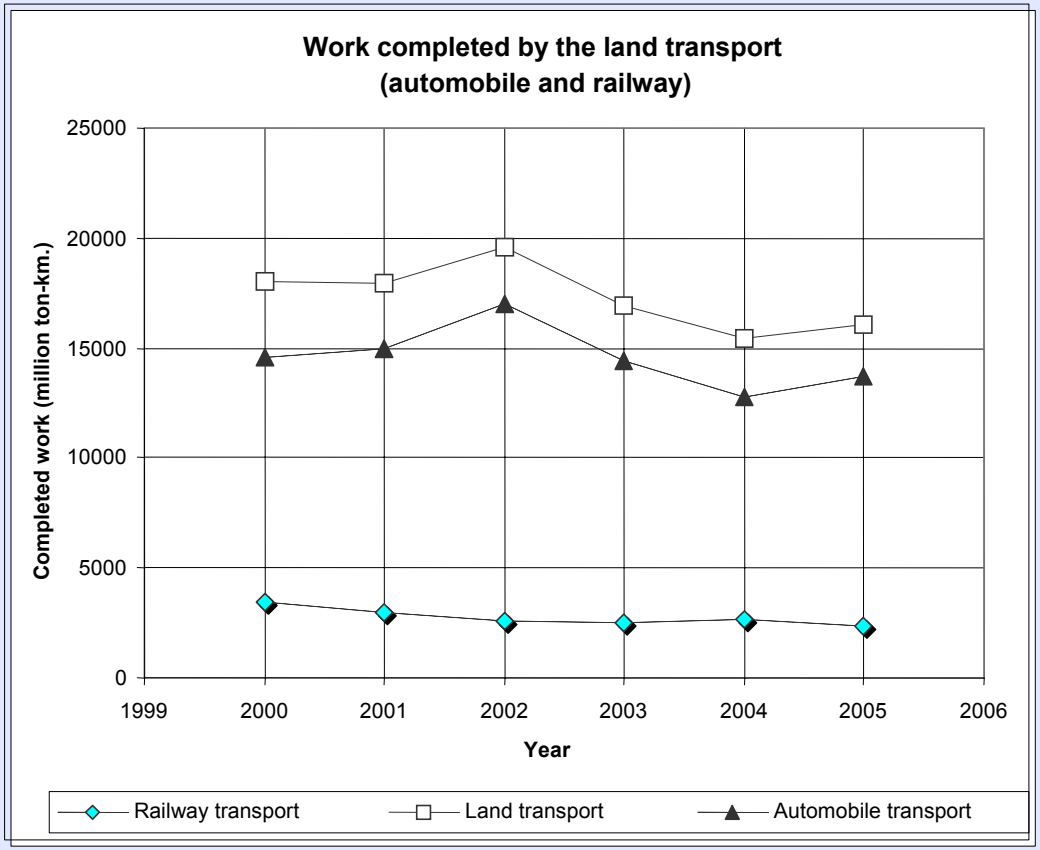
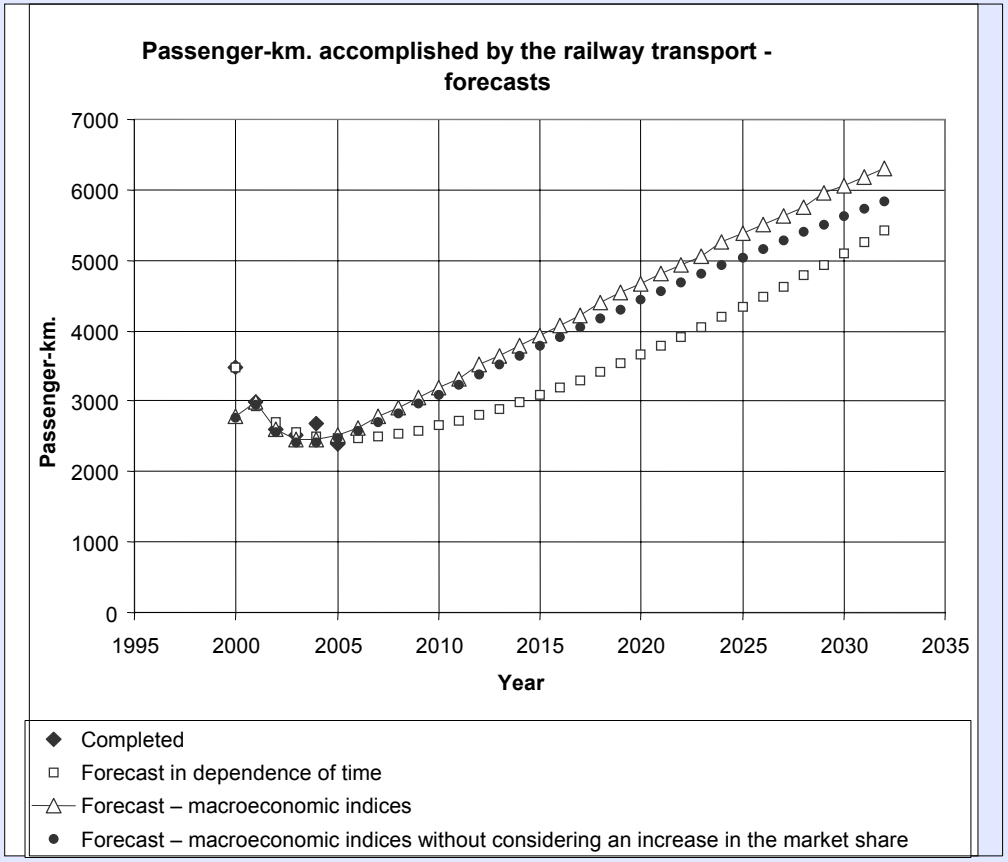


Types of forecasts:

1. Forecast based on the time trend – assumed to be the low level of forecast or pessimistic forecast and could be applied when considering the alternative, where “nothing is completed”.
2. Forecast based on the influence and the calculation of chosen macroeconomic factors, rendering account for the condition of the land transport and the market shares that belong to the railway and automobile transport in it. In case a conservation of the actual market share pertaining to the railway transport is foreseen, then the forecast in this basis would be realistic and the alternatives related to the realization of ERTMS/ETCS L1 only or ERTMS/ETCS L1 and then ERTMS/ETCS L2 could be applied.
3. If the upper approach is applied and an increase of the market share of the railway transport is reported, which is possible with the realization of ERTMS/ETCS L2, then this forecast is optimistic or forecast of high level.



Forecast of the completed passenger-km by the railway transport depending on time (low level of forecast or pessimistic forecast)

Forecasts		
Year	t	Passenger-kilometers
2000	1	3477,7744
2001	2	2933,0970
2002	3	2692,3001
2003	4	2566,6458
2004	5	2502,3689
2005	6	2476,8166
2006	7	2478,3370
2007	8	2500,1426
2008	9	2537,9243
2009	10	2588,7679
2010	11	2650,6042
2011	12	2721,9063
2012	13	2801,5116
2013	14	2888,5112
2014	15	2982,1788
2015	16	3081,9234
2016	17	3187,2558
2017	18	3297,7655
2018	19	3413,1038
2019	20	3532,9709
2020	21	3657,1071
2021	22	3785,2849
2022	23	3917,3037
2023	24	4052,9853
2024	25	4192,1705
2025	26	4334,7159
2026	27	4480,4921
2027	28	4629,3813
2028	29	4781,2763
2029	30	4936,0785
2030	31	5093,6974
2031	32	5254,0494
2032	33	5417,0570

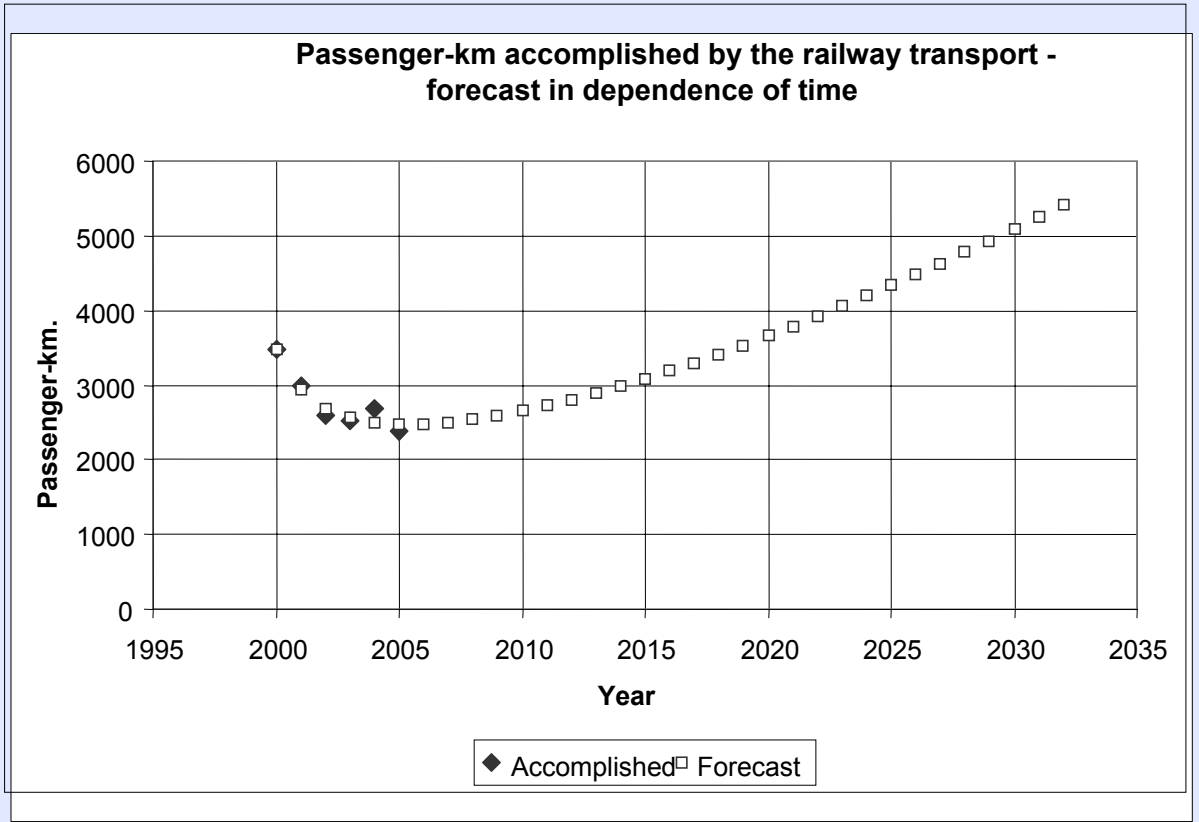
Model

$$Y = C_0 + \frac{C_1}{t^{1/4}} + C_2.t^{1,4}$$

$C_0 = -296,77;$

$C_1 = 3743,48;$

$C_2 = 31,07.$



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Forecasts – passenger transportations

Realistic, which is based on a 15% market share from the total completed passenger-km by the land transport. It represents the actual market share. In the forecast it is assumed that this market share will not increase. but it will conserve its size.

Optimistic, which assumes a gradual increase of the market share that belongs to the transport service. From the year 2007 to 2011 the market share is 15,4%, from the year 2012 to 2017 it is 15,60%, from 2018 to 2023 it represents 15,80%, from 2024 to 2028 it is 16%, and from the year 2029 to 2032 the forecasted market share is 16,20%.

Pessimistic – this is the forecast which is based on the dependency of the completed passenger-km by the railway transport in dependence of time. With this approach the influence that the quality of the service might have on the market share could not be reported. The market share is decreasing in this forecast.

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Determination of the maximum traffic capacity (MTC) of the railroad tracks.

Used methods.

The determination of the MTC can be obtained analytically or when the method of simulation modeling (with General Purpose Simulation System – GPSS, for example) is used. The method to be applied is the analytical determination of the MTC.

The analytical determination is done for each one of the defined railway sections.

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In the present condition of the railway infrastructure the determination of the MTC is done in the following way:

$N_m = \frac{A}{T_{per}} k\eta$ [number of trains]

$N_m^{total} = N_m - \varphi(\varepsilon_n - 1)N_{mов}$ [number of trains] or

$N_m^{total} = N_m \frac{1+\varphi}{1+\varphi.\varepsilon_n}$ [number of trains] where::

N_m Is the maximum traffic capacity in a parallel traffic, determined for a given category of trains (usually these are the freight trains)

$T_{пер}$ [min.] Is a period in the timetable, it depends on the type of the timetable;

k - number of trains which are let trough for one period of the timetable $T_{пер}$

η - quotient for using the MTC on the parallel timetable;

N_m^{total} -MTC of the non-parallel timetable, realistic timetable for motion;

$\varphi = \frac{N_n}{N_{mов}}$ - ratio between the passenger and freight trains in a given railroad track

ε_n - κ - quotient of removal of the passenger trains, which is usually greater than one and depends on the quality characteristics of the elaborated timetable for motion of the trains

$T_{per} = t^{even} + t^{odd} + \tau_A + \tau_B$ [min.], as t^{even} and t^{odd} Represent the time-motions in the corresponding destinations τ_A and τ_B being the corresponding train station intervals

A - resource of time with which the limiting MTC element possesses from the railway section, being this usually a middle-station with the greatest true to the present moment inclination, distance and greatest time-motion

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$A = 1440 - T_{прз} - T_{др}$ [min.], being $T_{прз}$ the average time in twenty-four hours, destined for gaps (windows) $T_{др}$ being the necessary time to let trough the other types of trains and the impossibility to let trains for another type of reason

In the case of double line, the period of the timetable is $T_{пер}^{direction} = t^{direction} + \tau_{пс}$ and it's defined for each one of the lines. The index "direction" defines the line and $\tau_{пс}$ represents an interval of the travel following in a normal timetable. Furthermore the MTC is determined for each line separately and k=1. Two levels of MTC are determined: a high level in the beginning of the forecast and a low level in the end of the forecast horizon. A tendency is observed and it consists of the following: with the time elapsed the work for maintaining the lines increases and this fact leads to an increase in the time-intervals defined:
$T_{прз}$ and $T_{др}$ and from here the resource of time A decreases

Having the given values of N_m, φ and ε_n the freight $N_{мов}$ and passenger N_n trains can be defined:

$$N_{мов} = N_m \frac{1}{1 + \varphi.\varepsilon_n};$$

$$N_n = N_m \frac{\varphi}{1 + \varphi.\varepsilon_n}.$$

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With the implementation of ERTMS/ETCS L1 or level 2 systems an accomplishment of the partially-package timetables is possible, containing the number of trains from package 2 or more. The intervals between the trains under ERTMS/ETCS L1 are grater with approximately 7-8 min., whereas under ERTMS/ETCS L2 they may reach up to 2 min. It is normal for them to reach 5 min.

$$N_m^{ч.пак} = \frac{A\gamma_{пак}}{T_{пер}^{пак}} k_{пак}\eta + \frac{A(1-\gamma_{пак})}{T_{пер}} k\eta ;$$

$N_m^{общо} = N_m^{ч.пак} - \varphi(\varepsilon_n - 1)N_{тов}$, where:

$k_{пак}$ Is the number of trains, i.e.. this is the number of trains that pass over one period of time of package let through

$\gamma_{пак}$ -percentage of the time, during which the trains are let through in package;

$T_{пер}^{пак}$ - period of the package timetable;

$N_m^{ч.пак}$ -MTC of the partially-package timetable

The period for package let through is defined as follows:

$T_{пер}^{пак} = T_{пер} + (k_{пак} - 1)(J^{четна} + J^{нечетна})$;

$J^{четна}$ и $J^{нечетна}$ -intervals of the trains in package.

With a double line, simply $T_{пер}^{посока} = J^{посока}$.

With the implementation of ERTMS/ETCS Level 1 the traffic capacity can be increased with 20-25% and the timetable that can be achieved is partially-package with the number of trains from package two. The greater package would increase the expenditures for equipment. The quotient of packages (the percentage of the day (24-hours), during which the trains are let trough in package) is determined on the basis of the MTC when the ERTMS/ETCS L1 is implemented, and it is obtained after the increase of the MTC in a normal timetable with the accepted percentage of 20-25%.
With the implementation of ERTMS/ETCS Level 1 the traffic capacity can be increased with 70-80% and the timetable that can be accomplished is the partially-package number of the trains in package three. The quotient of package is determined on the basis of the MTC with the implemented ERTMS/ETCS L2, which is obtained after the increase in the MTC in a normal timetable with the accepted percentage of 70-80% and increase the velocity of the trains with 20-30%.

Determination of the maximum traffic capacity of the railroad tracks.

Determination of the MTC in the alternative “nothing is done”

Determination of the MTC considering the alternative implementation of ERTMS/ETCS L1

Determination of the MTC considering the alternative implementation of ERTMS/ETCS L2

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With the implementation of ERTMS/ETCS L1 systems it is possible to meet the partially-package timetables containing the number of trains from package 2.
With the implementation of ERTMS/ETCS L2 systems it is possible meet the partially-package timetables containing the number of trains from package 3 or more.
In the calculations are used three trains per package.
The intervals between the trains, when having ERTMS/ETCS L1 are greater with approximately 7 – 8 min., whereas under ERTMS/ETCS L2 they may reach up to 2 min. It is normal for the intervals to be equivalent to 4 - 5 min.
With the implementation of ERTMS/ETCS L1 the traffic capacity can be increased with 20-25%, this fact lays in the base of the forecast of the supply.
With the implementation of ERTMS/ETCS L2 the traffic capacity can be increased with 70-80%, this fact lays in the base of the forecast of the supply.

With the implementation of ERTMS an increase in the speeds on the railway sections is also taken into account..

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1.Determination of the main scenarios (alternatives).
The main theoretical models taken from the point of view of the forecasts of market demand (transformed in traffic for the railway transport) and the supply (represented as MTC of the railway track observed), with which there is a definite sense to work with are three:

- **Base alternative or the alternative "nothing is done"**
- **Alternative at which, ERTMS/ETCS L1 is implemented**
- **Alternative at which, ERTMS/ETCS L2 is implemented**

2. Determination of the final forecasts for completed work and the traffic in the different sections, and totally for the network, taking into account the demand (the necessary traffic capacity), the supply (the maximum traffic capacity) and the influence that the quality of the offered product has on the market share.

3. Determination of the gross ton-km work and the train-km on the defined sections and totally for the network

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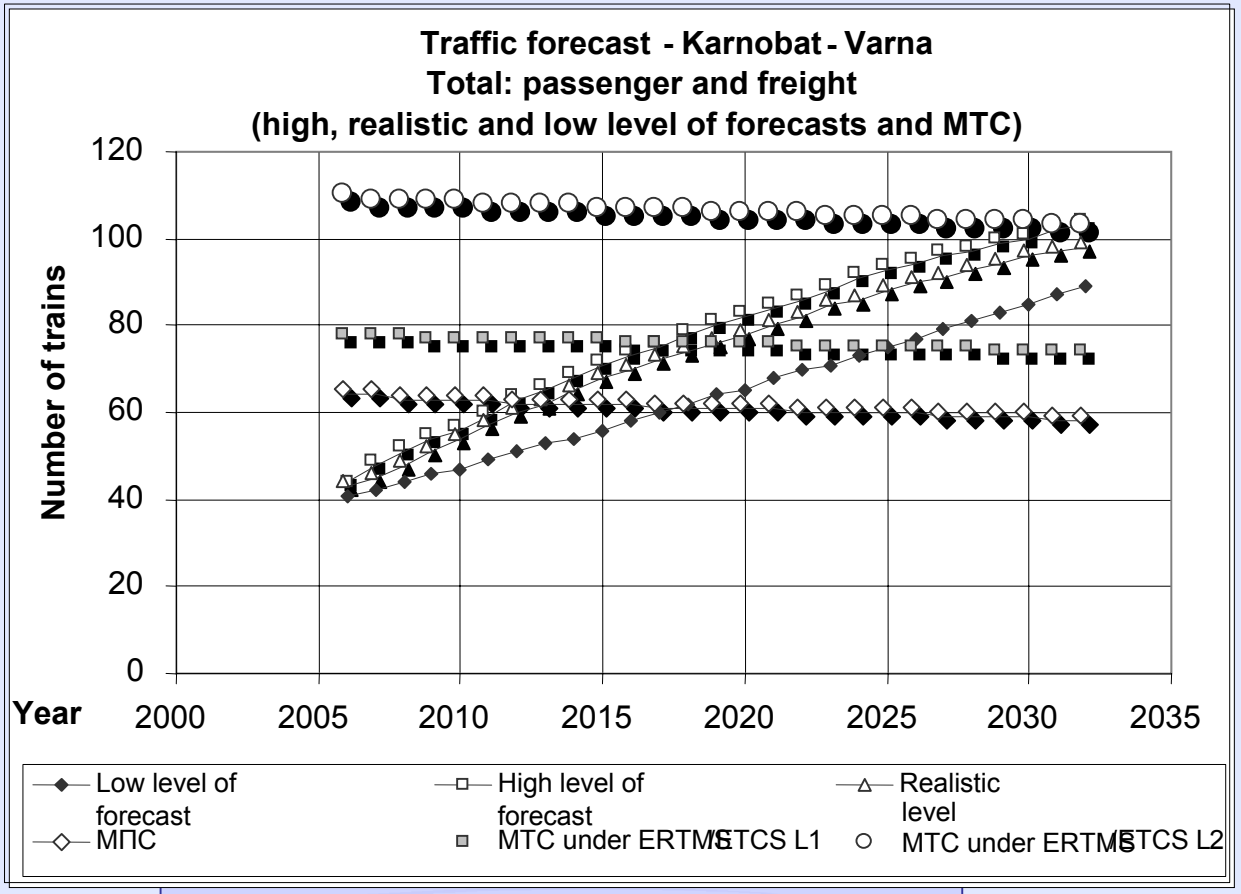
Forecasts related to the market demand (NTC) and supply (MTC)



NTC – necessary traffic capacity
MTC – maximum traffic capacity

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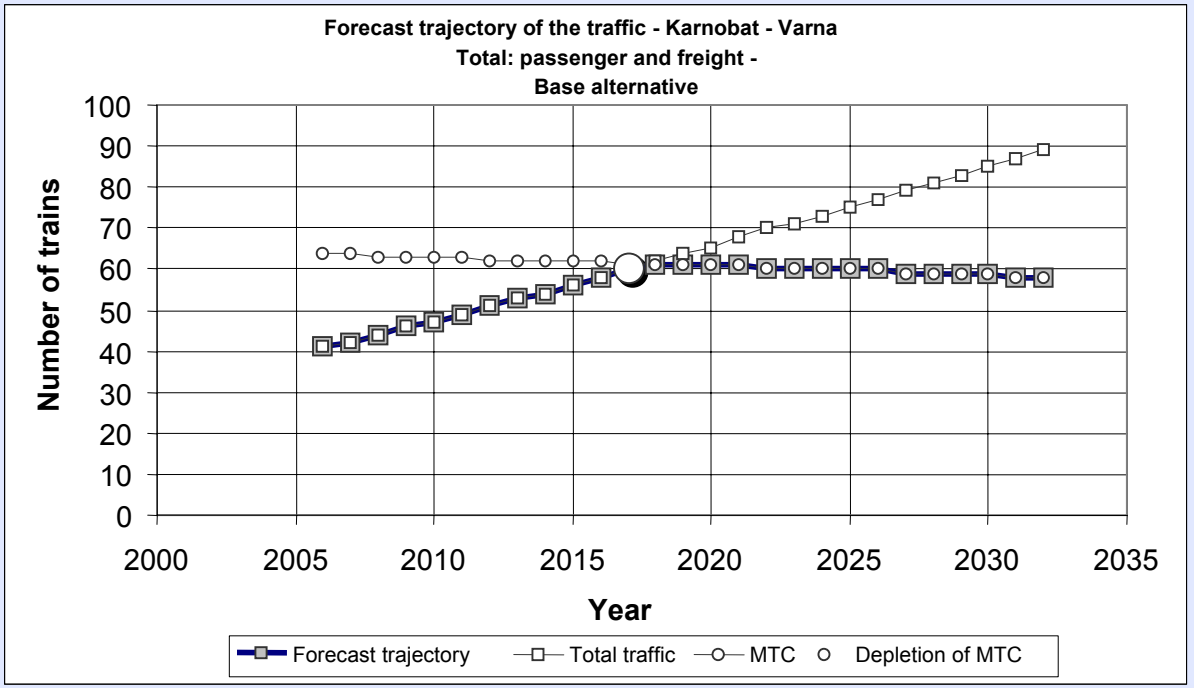
Forecast by alternatives (forecast trajectory) traffic (passenger and freight)



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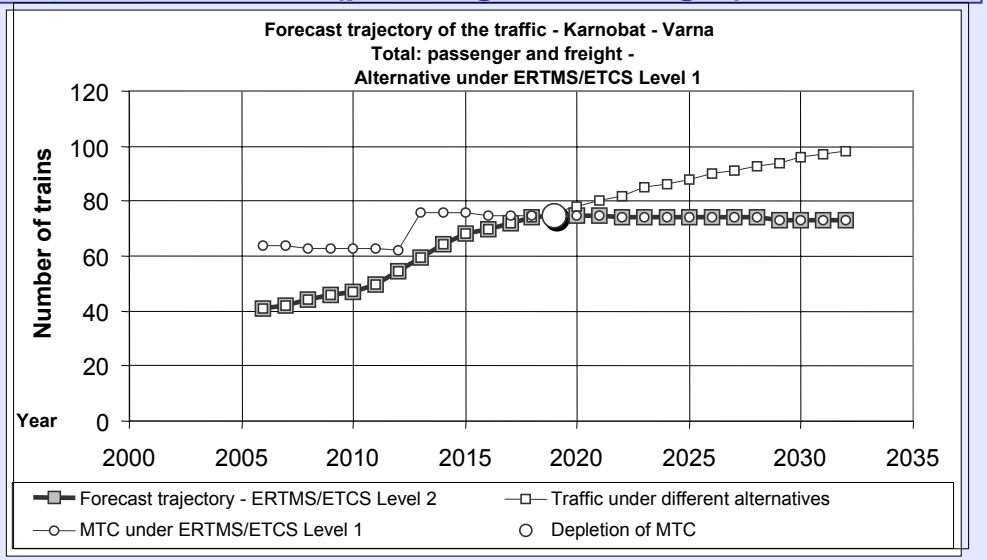

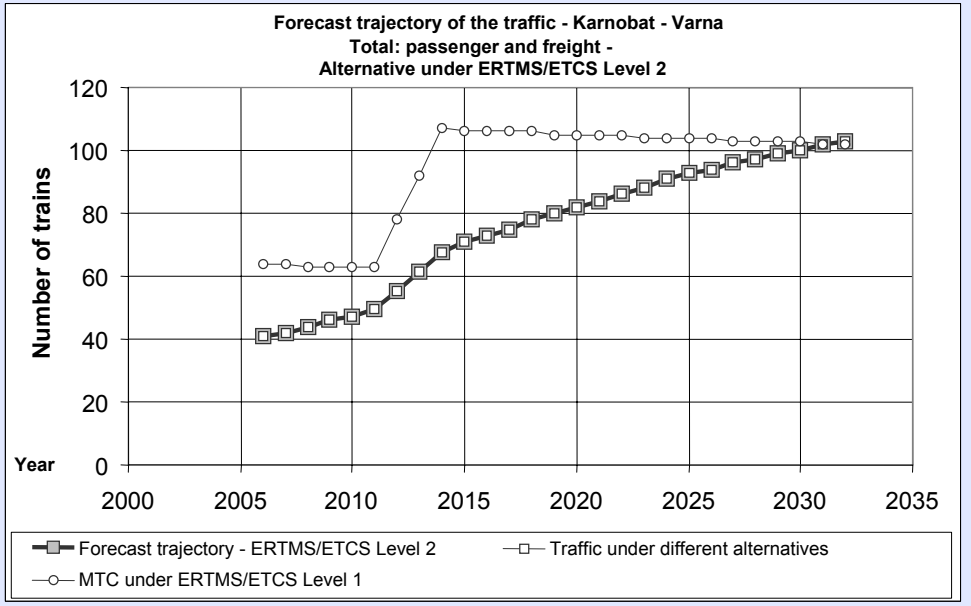

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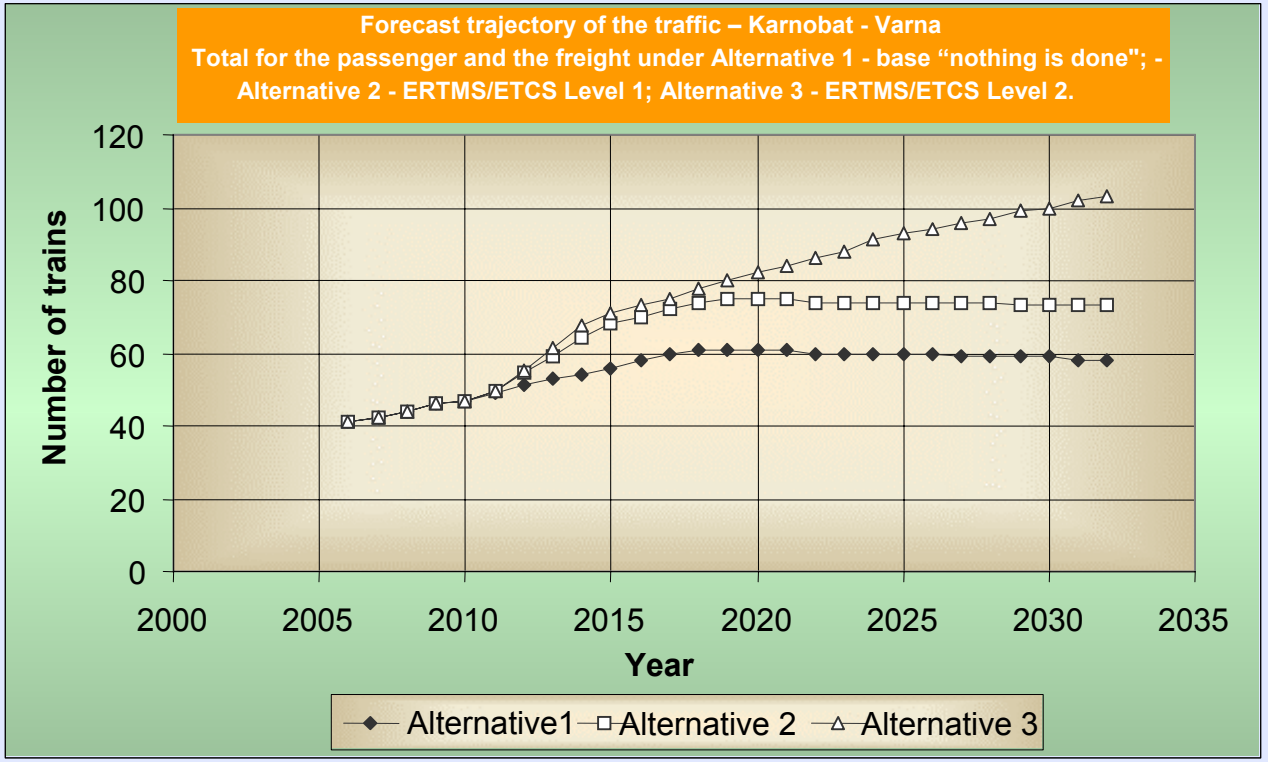
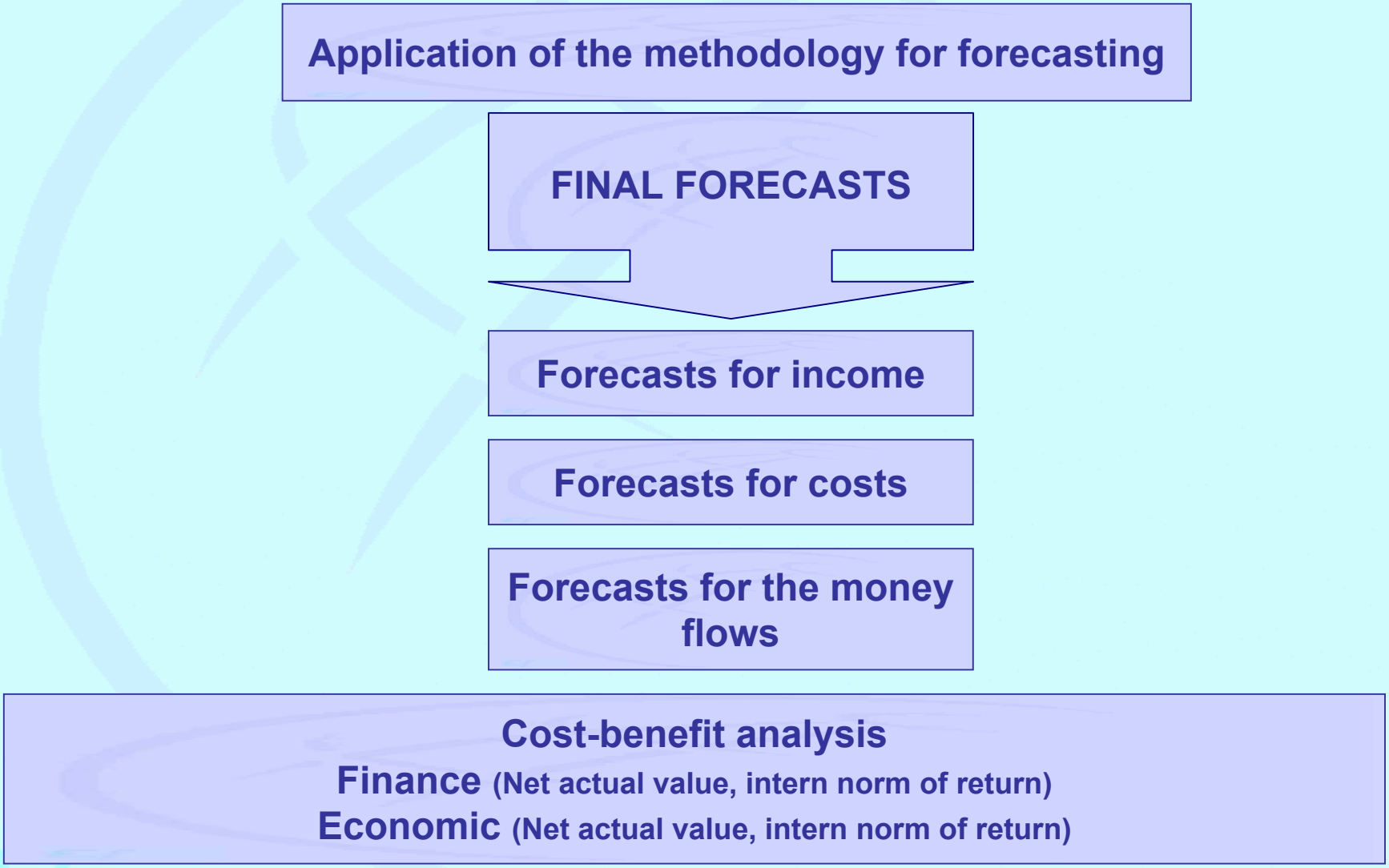
Forecasts in accordance with the alternatives traffic (passenger and freight)



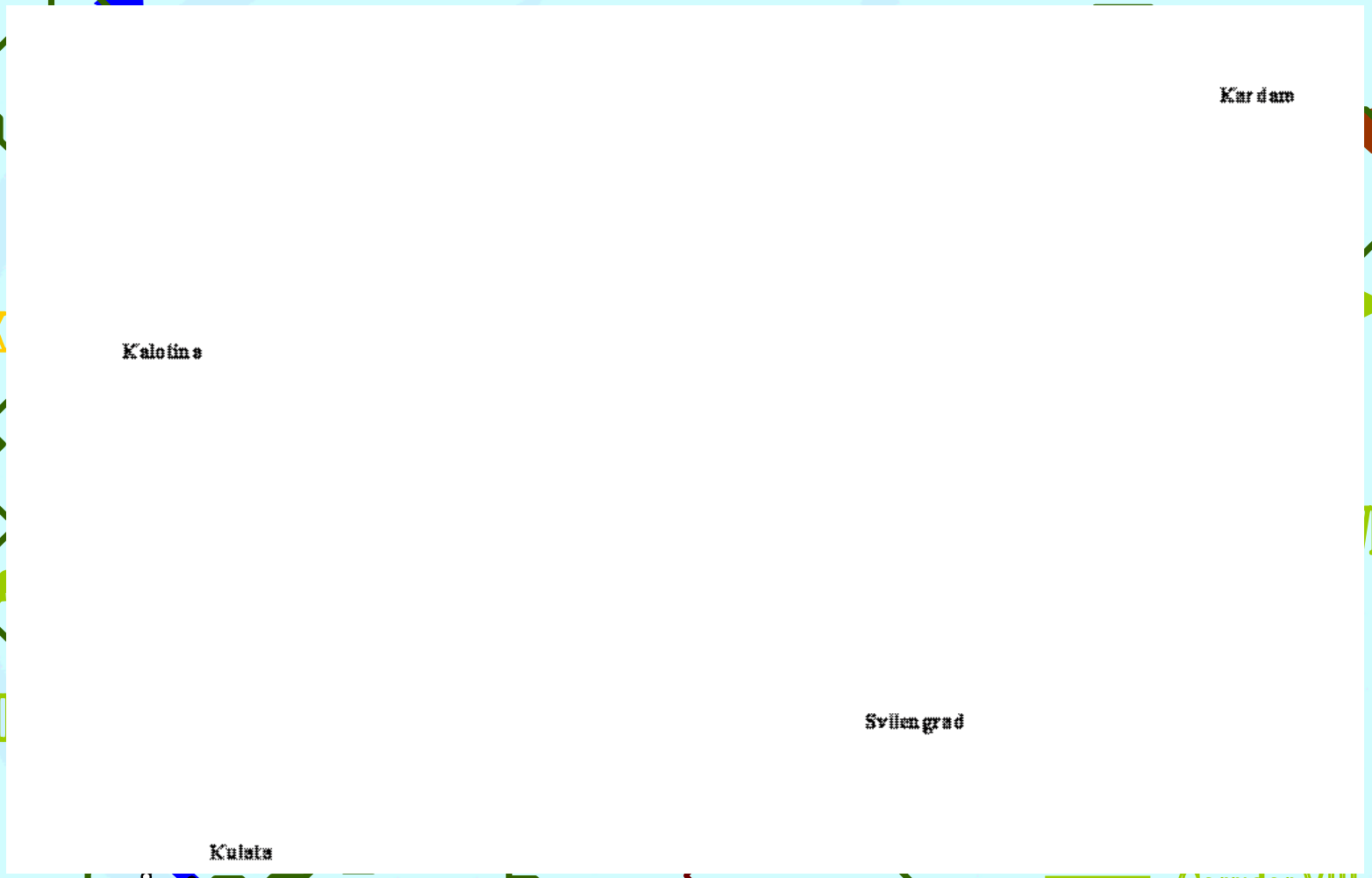
Place of the forecasts for the work and traffic of the railway network of the Republic of Bulgaria when applying the “Cost-benefit analysis”



National plan for implementation of ERTMS elaborated on the basis of:
- Traffic forecasts;
- Foreseeing the needed investments in the traveling/road and locomotion equipment;
- Cost-Benefit Analysis

The national plan for implementation of ERTMS is directed towards the building up of a modern and competitive railway network by using the full capacity the information and communication technologies have to offer, with the purpose being to achieve a efficient management of the traffic.
Speed, simultaneosity and integrity in the achievement of ERTMS, that might be treated as a strategic advantage and possibly lead to a maximum return in a long-term period.
The intentions of Bulgaria concerning the completion of the system ERTMS/ETCS are presented in the plan.
The choice was based on a preliminary cost-benefit analysis (CBA) and the project for realization in the period 2007-2013 in the Sector Operative Program Transport.
The main parameters are as follows: temporal horizon, improvement of the capacity after the implementation of the chosen type of ERTMS/ETCS; average increase in the traffic, measured in % per year, results from the CBA – benefits and needed investments.

Scheme
of Railway Lines of the Republic of Bulgaria



IV

X

VIII

VIII

VIII

IX

IV

Corridor VIII

Corridor IX

Railway lines of national importance

Transeuropean Corridor X
Kalotina – Sofia – Slivengrad
Distribution in three sections:
Kalotina – Sofia; Sofia – Plovdiv; Plovdiv – Dimitrovgrad – Svilengrad
Length – 358 km (one-track – 188 km.; doble-track – 170 km.; electrified – 211 km.; in process of electrification – 147 km.)
Necessary investments for ERTMS/ETCS Level 2: 82,058,399.0 euros; 229,214.24 euros per kilometre. For the activities in the preparation process – 16,411,688.00 euros

Transeuropean Corridor IX
Ruse – Gorna Oriahovitsa – Dimitrovgrad
(Dimitrovgrad – Svilengrad is also a part of the Corridor X and is included in the section Plovdiv – Svilengrad)
Distribution in two sections: Ruse – Gorna Oriahovitsa and Gorna Oriahovitsa – Dimitrovgrad)
Length – 310 km. (one-track – 310 km.; electrified – 310 km.)
Necessary investments for ERTMS/ETCS Level 2: 109,179,106.00 euros; 203,313.05 euros per kilometre. For the activities in the preparation stage – 21,835,821.20 euros

Transeuropean Corridor IV
Vidin – Sofia – Kulata
Distribution in three sections: Vidin – Mezdra; Mezdra – Sofia; Sovia – Kulata (Voluyak – Pernik included)
Length – 527 km. (one-track – 427 km.; doble-track – 110 km.; electrified – 537 km.)
Necessary investments for ERTMS/ETCS Level 2: 109,179,106.00 euros; 203,313.05 euros per kilometre. For the activities in the preparation process – 21,835,821.20 euros

Transeuropean Corridor VIII
Gyushevo – Radomir – Sofia – Plovdiv – Stara Zagora – Karnobat – Burgas/Varna –
(Sofia – Plovdiv is included in Corridor X)
Distribution in three sections: Plovdiv – Stara Zagora – Burgas; Karnobat – Varna; Gyushevo – Radomir (Sofia)
Length – 537 km. (one-track – 296 km.; doble-track – 241 km.; electrified – 314 km.; non-electrified – 223 km.; the section Plovdiv – Stara Zagora – Burgas – ETCS Level 1)
Necessary investments for ERTMS/ETCS Level 2: 105,532,428.00 euros; 196,522.21 euros per kilometre. For the activities in the preparation process – 21,106,486.00 euros

Railway lines of national importance
Sofia (Iliyantsi) – Karlovo – Zimnitsa; Mezdra – Gorna Oryahovitsa; Gorna Oryahovitsa – Sindel (Varna); Ruse – Kaspichan; Brusartsi – Lom
Length – 901 km. (one-track – 472 km.; doble-track – 429 km.; electrified – 901 km.)
Necessary investments for ERTMS/ETCS Level 2: 167,607,599.00 euros; 186,023.97 euros per kilometre. For the activities in the preparation process – 33,521,519.80 euros

Railway lines of regional importance
Filipovo – Karlovo; Razdelna – Kardam; Dimitrovgrad – Podkova
Length – 291 km. (one-track – 291 km.; electrified – 61 km.)
Necessary investments for ERTMS/ETCS Level 2: 48,056,855.00 euros; 165,143.83 euros per kilometre. For the activities in the preparation process – 9,611,371.00 euros

Total investments destined for ERTMS/ETCS L2, together with other elements necessary for an adequate functioning of ERTMS system – of which that sum:
- **683,261,131.00 евро**, from which:
- For the building of ERTMS/ETCS and other elements, such as computer train-station centralizations, optical cables and others in the railway network - **569,384,275.00 евро**;
- Destined for the activities in the preparation process - **113,876,856.00 евро**.

Main reasons for investments in locomotives and the locomotive equipment.

- **Exterior reasons**
  - The introduction of new systems for management of the trains and traffic in the European railway network (ERTMS/ETCS Level2 or ERTMS/ETCS Level1).
  - The requirements for operative compatibility of the locomotives.
- **Interior reasons**
  - Condition of the locomotives in the “Bulgarian state railways” EAD locomotive stock.
  - Forecast for increasing traffic.
  - Insufficient finance possibilities of the railway operators for the renewal of the old locomotive stock and accomplishment of operative compatibility.

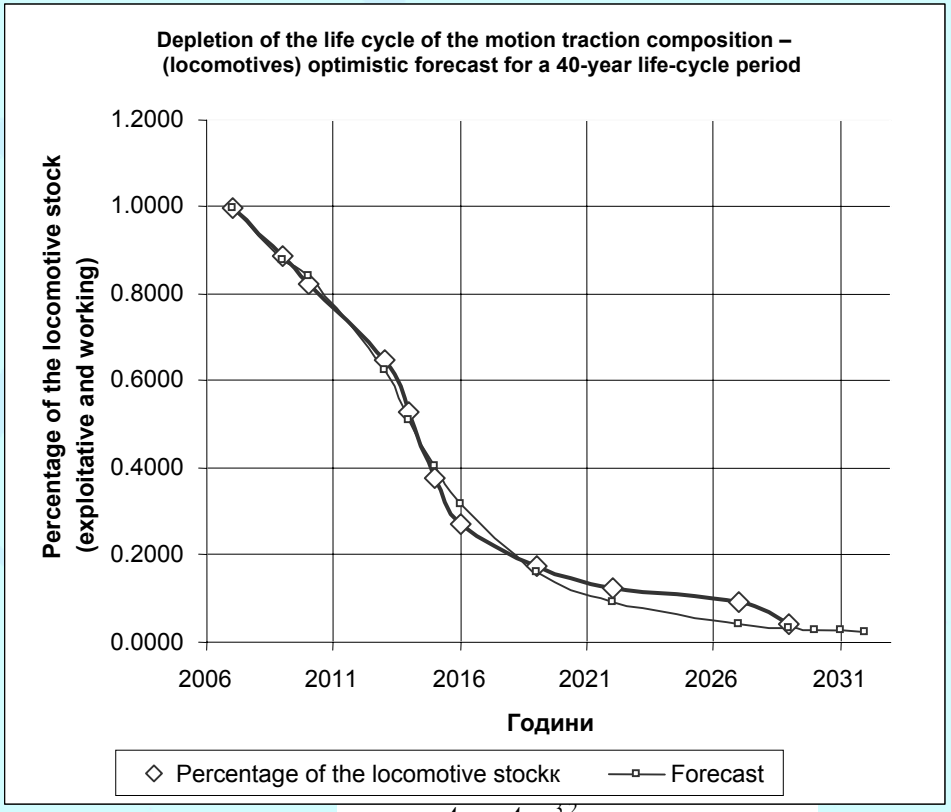
Forecast for the necessary number of locomotives to be replaced or for the equipment in dependency of their life-cycle for the period year 2007 – 2032.

Type of the forecasts:

Realistic forecast with a life-cycle per locomotive – 35 years
Optimistic forecast with a life-cycle per locomotive - 40 years
Exploitative locomotive stock – locomotives and Diesel trains towards the year 2007 – 595
Working locomotive stock towards the year 2007 – 269

Realistic forecast for the number of locomotives that will remain in the exploitation and working locomotive stock with a life cycle per locomotive - 35 years

	Realistic level of forecast with a life cycle of 35 years.		
	%	locomotive stock In exploitation	Working locomotives
2006			
2007	100.00%	595	269
2008	93.16%	554	251
2009	87.70%	522	236
2010	84.36%	502	227
2011	80.63%	480	217
2012	73.46%	437	198
2013	62.74%	373	169
2014	50.93%	303	137
2015	40.27%	240	108
2016	31.64%	188	85
2017	24.97%	149	67
2018	19.91%	118	54
2019	16.07%	96	43
2020	13.14%	78	35
2021	10.86%	65	29
2022	9.09%	54	24
2023	7.68%	46	21
2024	6.54%	39	18
2025	5.63%	33	15
2026	4.87%	29	13
2027	4.25%	25	11
2028	3.73%	22	10
2029	3.29%	20	9
2030	2.92%	17	8
2031	2.61%	16	7
2032	2.34%	14	6



Model:

$$Y = \frac{A_0 + A_1.x^{3.2}}{A_2 + A_3x^2 + A_4x^6};$$

$A_0 = 3.3857415;$

$A_1 = 0.0157363;$

$A_2 = 3.2842145;$

$A_3 = 0.1251436;$

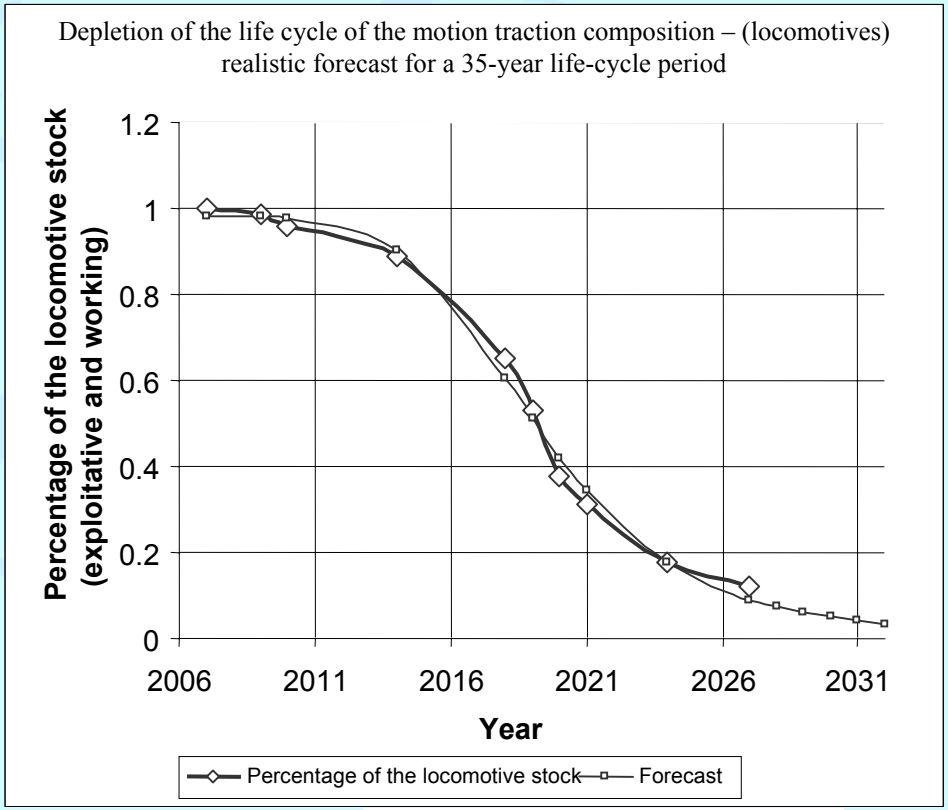
$A_4 = 7.374E-05;$

$x = 1,2,....,26;\ x = 1 - 2007$ год.;

$x = 2 - 2008$ год.; $x = 26 - 2032$ год.

Optimistic forecast for the number of locomotives that will remain in the exploitation and working locomotive stock having a life cycle per locomotive – 40 years.

	Optimistic level of forecast with a life cycle of 40 years.		
	%	locomotive stock In exploitation	Working locomotives
2006			
2007	100.00%	595	269
2008	98.04%	583	264
2009	97.91%	583	263
2010	97.63%	581	263
2011	97.00%	577	261
2012	95.77%	570	258
2013	93.59%	557	252
2014	90.06%	536	242
2015	84.88%	505	228
2016	77.99%	464	210
2017	69.62%	414	187
2018	60.37%	359	162
2019	50.97%	303	137
2020	42.09%	250	113
2021	34.20%	203	92
2022	27.49%	164	74
2023	21.98%	131	59
2024	17.54%	104	47
2025	14.01%	83	38
2026	11.24%	67	30
2027	9.05%	54	24
2028	7.33%	44	20
2029	5.98%	36	16
2030	4.90%	29	13
2031	4.04%	24	11
2032	3.36%	20	9



Model:

$$Y = \frac{A_0 + A_1 x^2}{A_2 + A_3 x^2 + A_4 x^5};$$

$A_0 = 2.8946461;$

$A_1 = 0.0001371;$

$A_2 = 2.9506104;$

$A_3 = 0.0005797;$

$A_4 = 7.208E-06;$

$x = 1,2,....,26;$ $x = 1$ - 2007 год.;

$x = 2$ - 2008 год.; $x = 26$ - 2032 год.

Forecast for the necessary locomotives based on the traffic forecasts for the period year 2007 – 2032.

Type of the forecasts:

Forecast for the necessary locomotives based on the traffic forecast considering the alternative “nothing is done”.

Forecast for the necessary locomotives based on the traffic forecast considering the alternative “Implementation of ERTMS/ETCS Level 1”.

Forecast for the necessary locomotives based on the traffic forecast considering the alternative “Implementation of ERTMS/ETCS Level 2”.

Forecasting the necessary investments for renewal of the locomotives with a depleted life cycle, incorporating the increasing traffic and equipment of the locomotives for ERTMS/ETCS Level1 or ERTMS/ETCS Level2

Investments for renewal of the locomotive stock with a depleted life cycle are determined for 35-year and 40-year life cycle.
The investments for increase in the locomotive stock with the purpose of incorporating the increasing traffic are determined for three alternatives:
"nothing is done, i.e.. no new systems are introduced to manage the trains and the traffic",
Implementation of ERTMS/ETCS L1 and implementation of ERTMS/ETCS L2.

All values are in million euros

	Alternative 1 (Nothing is done)		Alternative 2 (Implementation of ERTMS/ETCS Level 1)		Alternative 3 (Implementation of ERTMS/ETCS Level 2)		Investment field – minimum, maximum and average value of the annual investments		
	Investments in locomotives (annually) optimistic f. – million euros	Investments in locomotives (annually) realistic f. – million euros	Investments in locomotives (annually) optimistic f. – million euros	Investments in locomotives (annually) realistic f. – million euros	Investments in locomotives (annually) optimistic f. – million euros	Investments in locomotives (annually) realistic f. – million euros	Minimum annual investment in locomotives	Maximum annual investment in locomotives	Average annual investment in locomotives
2008	40.05	91.73	51.80	103.45	48.04	99.72	40.05	103.45	71.75
2009	23.46	79.14	25.51	81.20	26.31	81.97	23.46	81.97	52.72
2010	21.66	57.48	26.30	62.15	27.11	62.91	21.66	62.91	42.29
2011	25.43	57.31	63.65	95.34	90.19	121.79	25.43	121.79	73.61
2012	29.05	92.91	112.51	176.19	156.75	220.07	29.05	220.07	124.56
2013	39.03	131.04	136.93	228.58	177.87	268.94	39.03	268.94	153.98
2014	59.48	147.59	110.46	198.86	149.22	236.81	59.48	236.81	148.14
2015	74.68	134.82	96.95	157.28	122.67	182.33	74.68	182.33	128.50
2016	83.57	103.68	110.29	130.42	140.07	159.93	83.57	159.93	121.75
2017	110.42	90.30	125.83	105.68	156.76	136.91	90.30	156.76	123.53
2018	115.29	66.94	137.57	89.21	174.14	126.53	66.94	174.14	120.54
2019	115.38	58.96	123.12	66.69	159.34	103.79	58.96	159.34	109.15
2020	106.95	42.43	119.22	54.70	153.92	90.43	42.43	153.92	98.17
2021	99.57	39.08	108.99	48.45	124.39	64.74	39.08	124.39	81.74
2022	74.92	22.48	91.17	38.69	110.14	58.33	22.48	110.14	66.31
2023	64.76	16.27	78.10	29.61	102.30	54.42	16.27	102.30	59.29
2024	53.26	16.87	73.10	36.73	98.88	62.90	16.87	98.88	57.88
2025	47.02	22.78	62.90	38.64	80.43	56.43	22.78	80.43	51.60
2026	39.84	15.59	45.66	21.36	72.80	48.78	15.59	72.80	44.20
2027	25.28	9.10	50.81	34.62	66.25	50.23	9.10	66.25	37.67
2028	23.22	11.09	34.09	21.95	55.20	43.17	11.09	55.20	33.14
2029	19.80	7.67	27.16	15.03	66.99	54.95	7.67	66.99	37.33
2030	16.33	8.24	31.73	23.65	53.46	45.43	8.24	53.46	30.85
2031	10.27	6.23	22.34	18.29	43.87	39.86	6.23	43.87	25.05
2032	14.96	10.92	27.86	23.82	45.63	41.61	10.92	45.63	28.27
Total	1333.70	1340.63	1894.06	1900.60	2502.75	2512.97	841.34	3002.71	1922.03

Forecasting the necessary investments for the equipment if the locomotives for ERTMS/ETCS Level1 or ERTMS/ETCS Level2

Prices of equipment for:

Electrical locomotive	3.5	million euros
Equipment for ERTMS/ETCS L1	0.11	million euros
El. locomotive with equipment for ERTMS/ETCS Level 1	3.61	million euros
Equipment for ERTMS/ETCS L2	0.16	million euros
El. locomotive with equipment for ERTMS/ETCS Level 2	3.66	million euros

Alternative 2 (Implementation of ERTMS/ETCS Level 1)

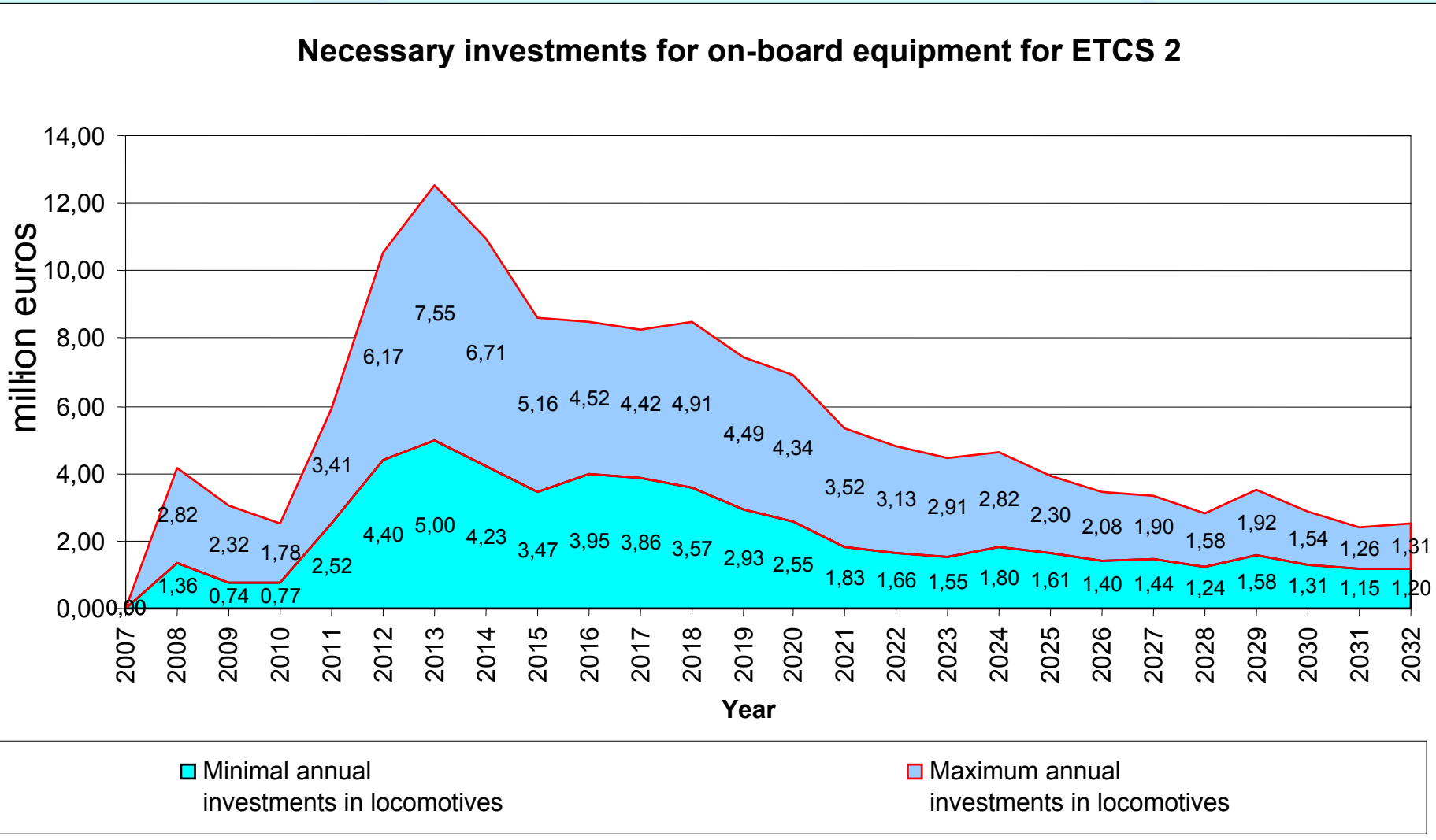
Investment field – minimum, maximum and average value of the annual investments

	Forecast increase – realistic forecast	Forecast increase – optimistic forecast	Renewal of the locomotive stock – realistic f.	Renewal of the locomotive stock – optimistic f.	Necessary el. locom. in the realistic f.	Necessary el. locom. in the optimistic f.	Necessary el. locom.per year in the realistic forecast	Necessary el. locom.per year in the optimistic f.	Investments in locomotives (annually) realistic f. – million euros	Investments in locomotives (annually) optimistic f. – million euros	Minimum annual investment in locomotives	Maximum annual investment in locomotives	Average annual investment in locomotives
2007	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00
2008	6	6	13	4	18	9	18	9	2.01	1.01	1.01	2.01	1.51
2009	9	9	23	4	33	14	14	5	1.58	0.50	0.50	1.58	1.04
2010	14	14	30	4	44	18	11	5	1.21	0.51	0.51	1.21	0.86
2011	24	24	36	6	60	29	17	11	1.84	1.23	1.23	1.84	1.54
2012	42	42	50	8	92	50	31	20	3.43	2.19	2.19	3.43	2.81
2013	62	62	71	12	133	74	41	24	4.46	2.67	2.67	4.46	3.57
2014	76	76	95	20	172	96	36	20	3.94	2.19	2.19	3.94	3.06
2015	84	84	117	30	200	113	28	17	3.12	1.92	1.92	3.12	2.52
2016	91	91	134	43	224	133	24	20	2.59	2.19	2.19	2.59	2.39
2017	97	97	147	60	244	157	19	23	2.10	2.50	2.10	2.50	2.30
2018	104	104	157	78	260	181	16	25	1.77	2.74	1.77	2.74	2.25
2019	108	108	165	96	272	204	12	22	1.33	2.45	1.33	2.45	1.89
2020	112	112	171	114	283	226	10	22	1.09	2.37	1.09	2.37	1.73
2021	116	116	176	129	292	246	9	20	0.97	2.17	0.97	2.17	1.57
2022	120	120	179	143	299	263	7	17	0.77	1.82	0.77	1.82	1.29
2023	123	123	182	154	305	277	5	14	0.59	1.56	0.59	1.56	1.08
2024	128	128	184	163	312	291	7	13	0.73	1.46	0.73	1.46	1.10
2025	133	133	187	170	319	303	7	11	0.77	1.26	0.77	1.26	1.02
2026	136	136	189	176	325	312	4	8	0.43	0.92	0.43	0.92	0.67
2027	140	140	190	180	330	321	6	9	0.69	1.02	0.69	1.02	0.86
2028	144	144	191	183	334	327	4	6	0.44	0.68	0.44	0.68	0.56
2029	145	145	191	186	336	331	3	5	0.30	0.54	0.30	0.54	0.42
2030	149	149	192	188	340	337	4	6	0.47	0.63	0.47	0.63	0.55
2031	152	152	193	190	344	341	3	4	0.37	0.45	0.37	0.45	0.41
2032	155	155	193	191	349	346	4	5	0.48	0.56	0.48	0.56	0.52
Investments for equipment totally for the period									37.48	37.53	37.48	37.53	37.51

Alternative 3 (Implementation of ERTMS/ETCS Level 2)

Investment field – minimum, maximum and average value of the annual investments

	Forecast increase – realistic forecast	Forecast increase – optimistic forecast	Renewal of the locomotive stock – realistic f.	Renewal of the locomotive stock – optimistic f.	Necessary el. locom. in the realistic f.	Necessary el. locom. in the optimistic f.	Necessary el. locom.per year in the realistic forecast	Necessary el. locom.per year in the optimistic f.	Investments in locomotives (annually) realistic f. – million euros	Investments in locomotives (annually) optimistic f. – million euros	Minimum annual investment in locomotives	Maximum annual investment in locomotives	Average annual investment in locomotives
2007	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00
2008	5	5	13	4	18	8	18	8	2.82	1.36	1.36	2.82	2.09
2009	9	9	23	4	32	13	14	5	2.32	0.74	0.74	2.32	1.53
2010	14	14	30	4	43	18	11	5	1.78	0.77	0.77	1.78	1.27
2011	28	28	36	6	64	33	21	16	3.41	2.52	2.52	3.41	2.97
2012	53	53	49	8	103	61	39	27	6.17	4.40	4.40	6.17	5.29
2013	81	81	69	12	150	92	47	31	7.55	5.00	5.00	7.55	6.27
2014	101	101	93	19	194	120	42	26	6.71	4.23	4.23	6.71	5.47
2015	113	113	113	29	226	142	32	22	5.16	3.47	3.47	5.16	4.32
2016	124	124	129	41	253	166	28	25	4.52	3.95	3.95	4.52	4.24
2017	136	136	141	57	277	193	24	28	3.86	4.42	3.86	4.42	4.14
2018	149	149	150	75	299	224	22	31	3.57	4.91	3.57	4.91	4.24
2019	159	159	158	92	317	252	18	28	2.93	4.49	2.93	4.49	3.71
2020	170	170	164	109	333	279	16	27	2.55	4.34	2.55	4.34	3.44
2021	178	178	169	125	347	303	11	22	1.83	3.52	1.83	3.52	2.68
2022	186	186	173	138	359	324	10	20	1.66	3.13	1.66	3.13	2.39
2023	194	194	176	149	370	343	10	18	1.55	2.91	1.55	2.91	2.23
2024	204	204	179	158	383	362	11	18	1.80	2.82	1.80	2.82	2.31
2025	212	212	181	165	394	377	10	14	1.61	2.30	1.61	2.30	1.95
2026	220	220	183	171	404	391	9	13	1.40	2.08	1.40	2.08	1.74
2027	228	228	185	176	413	404	9	12	1.44	1.90	1.44	1.90	1.67
2028	235	235	186	179	422	414	8	10	1.24	1.58	1.24	1.58	1.41
2029	245	245	187	182	433	428	10	12	1.58	1.92	1.58	1.92	1.75
2030	253	253	188	185	441	438	8	10	1.31	1.54	1.31	1.54	1.42
2031	260	260	189	186	449	446	7	8	1.15	1.26	1.15	1.26	1.20
2032	267	267	190	188	458	455	7	8	1.20	1.31	1.20	1.31	1.26
Investments for equipment totally for the period									71.09	70.88	70.88	71.09	70.99


Necessary investments for on-board equipment for ETCS 2
million euros
14,00
12,00
10,00
8,00
6,00
4,00
2,00
0,00
2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032
Year
0,00 2,82 2,32 1,78 3,41 6,17 7,55 6,71 5,16 4,52 4,42 4,91 4,49 4,34 3,52 3,13 2,91 2,82 2,30 2,08 1,90 1,58 1,92 1,54 1,26 1,31
0,00 1,36 0,74 0,77 2,52 4,40 5,00 4,23 3,47 3,95 3,86 3,57 2,93 2,55 1,83 1,66 1,55 1,80 1,61 1,40 1,44 1,24 1,58 1,31 1,15 1,20
Minimal annual investments in locomotives
Maximum annual investments in locomotives

Conclusion

The plan for implementation of ERTMS is a part of a more complex strategy for implementation of contemporary operatively compatible systems, designed to manage the motion of trains and the traffic of the railway network.

This strategy needs to include the following:

1. Strategy for carrying out the plan for implementation of ERTMS (European rail traffic management system).

The strategy has to include the corresponding stages, and to be based on the accepted plan for implementation of ERTMS in the Republic of Bulgaria, and also to be consistent with the programs for development of the security technology and telecommunication networks of National railway infrastructure company (NRIC).

The programs for implementation of ERTMS by the railway operators, acting in the nation's borders have to be consistent with the accepted strategy.

2. Strategy and plan for modernization of the signaling, security, telecommunication and information systems in the railway infrastructure.

3. Strategy for development of the railway network.

This strategy has to define the main parameters of the railway network after the realization of the new projects in the railway infrastructure and after the realization of the plan for implementation of ERTMS and the plan for modernization of the signaling, security, telecommunication and information systems.

4. Plan for the realization of changes in the normative base (laws, regulations and others)

This plan is related to the introduction of new and modern resources for management of the motion of trains, the traffic and the capacity.

The realization of this strategy would be possible when the envisaged investments are assimilated.