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ANNUAL AVERAGE DAILY TRAFFIC FORECASTING USING DIFFERENT TECHNIQUES

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Abstract. This paper describes annual average daily traffic (AADT) forecasting for the Lithuanian highways using a forecasting method used by Idaho Department for Transportation, growth factor, linear regression and multiple regression. AADT forecasts obtained using these methods are compared with the forecasts evaluated by traffic experts and given in references. The results show that the best Lithuanian traffic data are obtained using Idaho forecasting method. It is assumed that the curve of AADT change should be exponential in the future.

Keywords: AADT, AADT forecasting, AADT forecasting using linear regression, AADT forecasting using multiple regression, AADT forecasting using growth factor.

1. Introduction

Average annual daily traffic (AADT) defines the number of vehicles crossing a road section per day. AADT measurements are performed constantly and forecasts of AADT value are being done. AADT intensity forecasts are used to plan road reconstruction, to determine what kind of upkeep and maintenance work should be done when investments into road infrastructure will bring profit and to determine how busy road traffic will be in the future.

The level of AADT value can be influenced by a number of factors, some of which can't be easily evaluated. These factors are: AADT variation in the past, changes in the economy, changes in the number of vehicles and citizens, average distance covered by a vehicle, changes in the situation of urban and industry areas, fuel prices etc. All these factors make forecasting complicated.

There were a few attempts to make AADT intensity forecasts in Lithuania. One of them included AADT forecasts on the Lithuanian highway and state roads for 2005-2025 interval [1]. These forecasts were built based on forecasts of average distance, covered by one vehicle, gross domestic product (GDP) forecasts, number of citizens change forecasts, number of vehicles in the country change forecasts, changes in the situation of urban areas, development of transport corridors and AADT value change in each road section during 1995-2004.

In this paper we will present AADT value forecasts using different techniques used abroad. Average AADT value for the Lithuanian highway road class will be used in forecasting. Average AADT value for road class will permit us to reduce AADT measurement error. Forecasting data used are displayed in Table 1 [1–10].

Table 1. Change of AADT average for the Lithuanian highways during 1994–2004

Year	AADT, auto/day	Highways used in calculation
1994	3793	-
1995	3837	A1-A13
1996	4477	A1-A13
1997	4904	A1-A13
1998	4816	A1-A13
1999	4674	A1-A17
2000	4791	A1-A17
2001	5610	A1-A17
2002	5755	A1-A17
2003	5971	A1-A17
2004	5823	A1-A17

2. Practice of forecasting in Idaho, USA

The Idaho Transportation Department uses (1) equation for AADT forecasting [11].

$$E_{t+n} = E_t \times (1+g)^n, \quad (1)$$

where: E_{t+n} – AADT value of *t* year, forecasted *n* years in the future; E_t – base year AADT value, observed during t year; g – annual AADT growth rate.

Average annual AADT growth rate is calculated using (2) equation:

$$g = \sqrt[k]{\frac{E_t}{E_{t-k}}} - 1, \quad (2)$$

where: k – a number of years between the first and the last AADT data value.

Fig 1 displays the results of using this method and the Lithuanian data (Table 1).

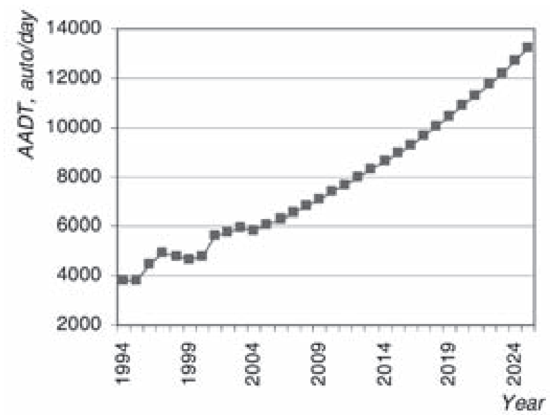

Fig 1. Forecast of average AADT value for the Lithuanian highways using a forecasting method used in Idaho, USA

3. AADT forecasting using a growth factor

Montana Department of Transportation (USA) and some other institutions use growth factors to forecast AADT value. The method is easy to use. The method assumes that the past trends in percent increase in traffic volume each year will continue into the future. Average error of the method is approximately 28.7 percent [11]. Table 2 displays equations describing the most common types of growth.
where: E_t – base year AADT value observed during t year; a, b – constants.

Results of forecasting using this method and (6) equation are displayed in Fig 2.

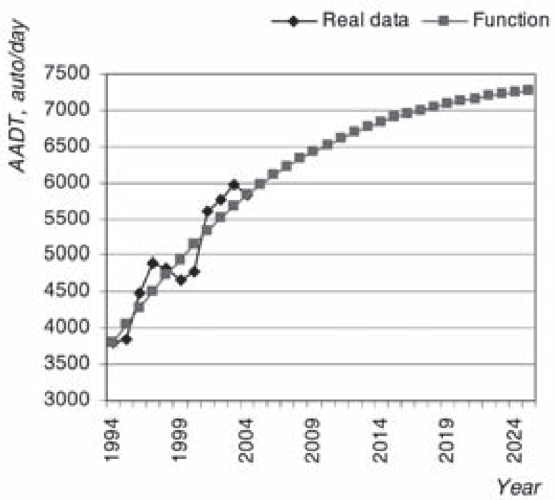

Fig 2. Forecast of average AADT value for the Lithuanian highways using a growth factor forecasting method

4. AADT forecasting, using regression

Two types of regression will be used to forecast AADT volume:

1) linear regression;
2) multiple regression.

Table 2. The most common types of growth used in AADT forecasting method using a growth factor

No	Function	Growth rate
(3)	$\ln(E_t) = a + b \times t$	b
(4)	$E_t = a + b \times t$	$\frac{b}{(a + b \times t)}$
(5)	$E_t^2 = a + b \times t$	$\frac{b}{2 \times (a + b \times t)}$
(6)	$\ln(E_t) = a + b \times e^{\frac{-t}{10}}$	$\left(\frac{-b}{10}\right) \times e^{\left(\frac{-t}{10}\right)}$
(7)	$\ln(E_t) = a + b \times [\ln(t+1)]$	$\frac{b}{t+1}$
(8)	$E_t = a + b \times [\ln(t+1)]$	$\frac{b}{t \times [a + b \times \ln(t+1)]}$

Using regression we can estimate the influence of economic and demographic factors on AADT.

A general example of linear regression is displayed by (9) equation.

$$E_t = a_0 + a_1 \times X_{1t} + ... + a_n \times X_{nt} + \varepsilon, \quad (3)$$

where: E_t – AADT value, observed during t year; $X_{1t}...X_{nt}$ – values of economic and demographic factors during t year; $a_0..a_n$ – constants; ε – error.

We will build a linear regression function using the following economic and demographic factors:

1. gross National Product (GNP);
2. number of citizens in the country;
3. number of vehicles at the end of the year.

Table 3 displays the data describing the change of an economic and demographic factor during 1996-2004.

Equation (10) displays linear regression function received.

$$E_t = 105932150 - 0.0064 \times X_{2t} - 26.7873 \times X_{3t} + 0.0835 \times X_{1t}, \quad (4)$$

where: E_t – AADT value of t year; X_{1t} – GNP for one citizen in 2000 year's prices during year t; X_{2t} – number of vehicles during t; X_{3t} – number of citizens during year t.

(10) equation's R^2=0.9684 is close to 1. This means that the equation represents measured AADT values well, and forecasts of future values may be good too. Table 4 displays the correlation between economic and demographic factors and AADT.

As we can see from Table 4 there is negative correlation between average annual number of citizens and average AADT in highways. This means that traffic volume increases with the reduction of the number of citizens. This situation is not logical. Negative correlation is close to -1, and it means that statistical bind between these two items is strong. Table 5 displays the prognosis of economic and demographic factors.

Forecasts obtained using linear regression (10) are displayed in Fig 3.

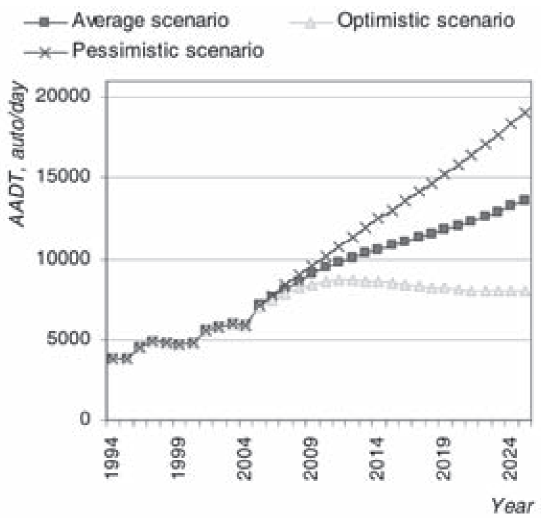

Fig 3. Forecast of average AADT value for the Lithuanian highways using linear regression

Table 3. Economic and demographic factors of Lithuania during 1996–2004 [12]

Year	GNP per citizen in 2000 year's prices (Lt)	Number of vehicles at the end of the year	Average annual number of citizens (thousands)
1996	8 965	924 524	3 601,6
1997	11 014	1 024 935	3 575,2
1998	12 503	1 129 849	3 549,3
1999	12 303	1 233 651	3 524,2
2000	13 101	1 317 716	3 499,5
2001	13 950	1 280 096	3 481,3
2002	14 975	1 333 114	3 469,1
2003	16 436	1 414 806	3 454,2
2004	18 174	1 479 364	3 435,6

Table 4. Correlation between economic and demographic factors and AADT

	Number of vehicles at the end of the year	Average annual number of citizens	GNP per citizen in 2000 year's prices
Average AADT in highways	0,86	-0,93	0,96

Table 5. Prognosis of economic and demographic factors of Lithuania [13]

Year	Average scenario			Optimistic scenario			Pessimistic scenario		
	GNP per citizen in 2000 year's prices (Lt)	Number of all types of vehicles at the end of the year	Number of citizens	GNP per citizen in 2000 year's prices (Lt)	Number of all types of vehicles at the end of the year	Number of citizens	GNP per citizen in 2000 year's prices (Lt)	Number of all types of vehicles at the end of the year	Number of citizens
2005	18 726	1 432 796	3 406 269	19 620	1 452 532	3 408 618	17 852	1 416 827	3 403 911
2006	19 962	1 443 412	3 387 037	21 411	1 473 600	3 392 205	18 578	1 418 889	3 381 869
2007	21 220	1 454 321	3 368 978	23 302	1 495 481	3 378 242	19 278	1 420 757	3 359 715
2008	22 536	1 465 649	3 352 333	25 336	1 518 383	3 367 056	19 985	1 422 503	3 337 620
2009	23 911	1 475 828	3 337 292	27 523	1 539 927	3 358 816	20 698	1 423 212	3 315 784
2010	25 370	1 486 617	3 323 953	29 898	1 562 756	3 353 599	21 437	1 423 974	3 294 377
2011	26 867	1 498 049	3 312 330	32 419	1 586 885	3 351 293	22 159	1 424 833	3 273 490
2012	28 398	1 510 078	3 302 271	35 087	1 612 252	3 351 632	22 861	1 425 797	3 253 129
2013	29 960	1 522 622	3 293 543	37 905	1 638 731	3 354 238	23 540	1 426 803	3 233 142
2014	31 548	1 535 328	3 285 348	40 873	1 665 685	3 357 722	24 192	1 427 799	3 213 406
2015	33 157	1 544 799	3 277 446	43 992	1 687 897	3 361 728	24 814	1 426 776	3 193 734
2016	34 782	1 554 252	3 269 641	47 261	1 710 293	3 366 000	25 402	1 425 646	3 174 037
2017	36 417	1 563 622	3 261 793	50 678	1 732 779	3 370 346	25 953	1 424 356	3 154 196
2018	38 056	1 572 848	3 253 778	54 241	1 755 259	3 374 581	26 464	1 422 876	3 134 148
2019	39 692	1 581 862	3 245 459	57 946	1 777 648	3 378 545	26 932	1 421 154	3 113 782
2020	41 359	1 589 798	3 236 736	61 846	1 798 600	3 382 110	27 382	1 418 680	3 093 009
2021	43 055	1 597 414	3 227 499	65 947	1 819 320	3 385 169	27 812	1 415 900	3 071 776
2022	44 777	1 604 682	3 217 705	70 254	1 839 752	3 387 634	28 221	1 412 774	3 050 004
2023	46 523	1 611 557	3 207 274	74 772	1 859 852	3 389 442	28 608	1 409 284	3 027 663
2024	48 291	1 618 033	3 196 212	79 505	1 879 612	3 390 600	28 971	1 405 414	3 004 726
2025	50 078	1 624 089	3 184 488	84 459	1 899 002	3 391 075	29 310	1 401 151	2 981 173

Table 6. Multiple regression equations built using data from Table 5

No	R^2 value	Equation
(11)	0,9506	$E_t = 51389{,}50668 + 0{,}00001 \times X_{1t}^2 - 0{,}000000003 \times X_{2t}^2 - 0{,}00345 \times X_{3t}^2$
(12)	0,9007	$E_t = -63254{,}2 + 0{,}9 \times X_{1t} + \frac{5748402416{,}7}{X_{2t}} + \frac{219409571{,}1}{X_{3t}}$
(13)	0,9213	$E_t = 792625 + 0{,}000003 \times X_{1t}^2 - 6717{,}8 \times ln(X_{2t}) - 84969{,}4 \times ln(X_{3t})$
(14)	0,9623	$E_t = 169120{,}2 + 2313{,}3 \times ln(X_{1t}) - 16{,}2 \times \sqrt{X_{2t}} - 2833{,}4 \times \sqrt{X_{3t}}$
(15)	0,9579	$E_t = 36384{,}1 - 0{,}01 \times X_{2t} + 2423{,}6 \times ln(X_{1t}) - 0{,}036 \times X_{3t}^2$

As we can see from Fig 3 the forecasts using pessimistic scenario are higher than the forecasts using optimistic and average scenarios. The purpose of this is negative constants in (10) equation.

Now we will build forecasts using multiple regression and the same data. Some of the multiple equations tested are displayed in Table 6.

Variables in Table 6: E_t – AADT value of t year; X_{1t} – GNP for one citizen in 2000 year's prices during year t; X_{2t} – number of vehicles during year t; X_{3t} – number of citizens during year t.

As we can see from Table 6, the highest value of R^2 has equation no. 14. Forecasts using this multiple regression equation are displayed in Fig 4.

As we can see from Fig 4 a pessimistic scenario has again higher value than optimistic and average scenarios.

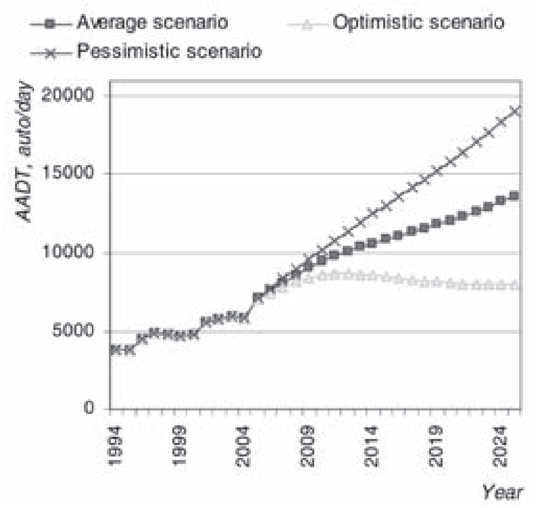

Fig 4. Forecast of average AADT value for the Lithuanian highways using multiple regression

5. Conclusions

Let's compare the calculated average AADT value forecasts for the Lithuanian highways [13] with forecasts obtained using here described methods (Table 7).

Forecasts from [12] references are built considering opinion of traffic experts, that's why we will compare them with other forecasts (Table 8).

Table 8 shows that the best results are obtained by Idaho method. As long as the number of citizens in Lithuania is decreasing and economy is growing, AADT value growth should decrease in the future. That's why probably the curve of AADT forecast should look like the one presented in Fig 2. Which forecast is the best, we will see in the future.

Table 7. Forecasts of AADT value for the Lithuanian highways using different methods

Year	Forecast from [12] reference source	Idaho (USA) method	Growth factor	Linear regression	Multiple regression
2005	6 020	6 054	5 965	7 086	7 083
2006	6 236	6 295	6 097	7 637	7 627
2007	6 456	6 545	6 218	8 156	8 135
2008	6 682	6 805	6 330	8 639	8 605
2009	6 908	7 076	6 433	9 091	9 042
2010	7 141	7 357	6 528	9 501	9 435
2011	7 380	7 649	6 615	9 865	9 777
2012	7 625	7 953	6 695	10 185	10 074
2013	7 876	8 269	6 768	10 469	10 330
2014	8 132	8 598	6 835	10 740	10 569
2015	8 375	8 939	6 896	11 025	10 817
2016	8 622	9 295	6 952	11 309	11 060
2017	8 870	9 664	7 003	11 596	11 300
2018	9 120	10 048	7 049	11 889	11 541
2019	9 371	10 447	7 091	12 190	11 786
2020	9 620	10 863	7 130	12 513	12 048
2021	9 870	11 294	7 165	12 853	12 322
2022	10 122	11 743	7 197	13 212	12 610
2023	10 374	12 210	7 225	13 594	12 916
2024	10 627	12 695	7 252	13 996	13 237
2025	10 879	13 199	7 276	14 421	13 577

Table 8. Comparison of forecasts from [12] references with forecasts obtained using other methods

Forecasting method	Maximum absolute error	Average absolute error
Idaho (USA) method	21,33 %	8,37 %
Growth factor	33,12 %	17,27 %
Linear regression	33,67 %	30,13 %
Multiple regression	32,48 %	27,10 %

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