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Error Estimation of Vehicle Traffic Intensity Prediction in an Urban Environment

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Abstract. In this article is proposed a method for forecasting vehicle traffic intensity in urban conditions and provides an estimate of the forecasting error. For input data in this study are used: the number of vehicles that have passed through a location of the road, based on data collected by observations; meteorological conditions; the day of the week; the season. For this purpose, database processing methods, statistical and stochastic methods are used.

INTRODUCTION

The forecasting of traffic intensity is a topic of considerable importance for the daily activity of a person in urban areas.

In the recent years there are numerous research efforts in this domain such as [3, 9, 11, 13, 14, 15, 16, 17], where different authors try to evaluate different proposed methods to control the traffic in cities around the world. In [11] research is focused on two level model for predictive control in large urban networks, while [13] use adaptive algorithm for same purpose but cities are middle sized. Other intelligent management and analysis system for smart cities is presented in [9]. It includes all infrastructure equipment for road monitoring and control such as: cameras, sensors, data analysis tool, communication networks and so on. The main goal is to reduce the pollution, improve insurance and minimize the time spend in vehicle. Special attention instigates artificial bottleneck in many crossways. [14] presents the energy flow management of many electric vehicle charges and its impact on micro-grids and assesses the potential for implementing a flexible energy flow management strategy. Modeling and control from a neural network of a hybrid electrical traction system of a vehicle is presented in [15]. The authors' goal in [16,17] is vehicle safety, with [16] offering Stereo Vision System to avoid a frontal collision, and [17] offering practical speed estimation methods by offering a microprocessor system with AMR sensors.

Authors in [3] discuss opportunities and challenges in developing cities, connect with signal light control in real time. Actually urban traffic in China's city is one of the hardest traffic problem in the world. Evaluation of such complex task is depict in [1]. Paper aim to reduce congestion, pollution, accidents and not least social consumption. Other work on smart signal traffic control is presented in [4]. This agent based model utilize reinforcement learning mechanism to improve automobile stream involved in traffic between intersections.

Other interesting idea for signal control based on fuzzy control and neural network is presented in [2]. Simulation results shows different rates of improvement in average delay, queue length and traffic capacity. Next related paper, [6] is an iterative strategy for oversaturated city network. By the use of an improved store and forward modelling

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approach is demonstrated that two interactive learning control schemes improve considerably the tracking error of traffic density.

In [7] is presented a layout research on traffic information sign of a ring expressway in Chongqing, China. The presented research demonstrates the influence of traffic information signs on the congestion of highway junctions. Different point of view is present in [12]. After traffic modelling and level of service definition, the authors submit dynamic models of traffic flow. Furthermore, the proposed models describe the inner structure, relationship and ideology behind flow and infrastructure. Further expand the analogy topic can be seen in [10]. The accent is on traffic simulation and analysis of impact in urban construction projects. In such condition proposed systematic method shows better distribution in traffic flow. Price is yet a problem [8] in this area. With not so expensive devices, waiting time and traffic volume can be seriously improved most of the time during the day. One more interesting idea that can combine with others can be seen in [5]. Except low price, green energy to be topic of the day. Furthermore, various parameters involve in vehicle density at the junction are estimate in all directions to ensure better flow in different directions.

In the present study is proposed a method for forecasting vehicle traffic intensity in urban conditions and provides an estimate of the forecasting error.

For input data in this study are used:

- the number of vehicles that have passed through a location of the road, based on data collected by observations;
- meteorological conditions;
- the day of the week;
- the season.

For this purpose, database processing methods, statistical and stochastic methods are used.

DESCRIPTION OF TRAFFIC INTENSITY

The intensity of movement is measured in a specific profile for a given period of time. Intensity q represents the number of vehicles passed through the profile N for a given measurement period T:

$$q = \frac{N}{T}. \tag{1}$$

The total measurement time may be expressed as the sum of the time intervals h_i between vehicles:

$$T = \sum_{i=1}^{N} h_i. \tag{2}$$

If in the first equation the period of time of measurement T is replaced by the second equation, then:

$$q = \frac{N}{\sum_{i=1}^{N} h_i} = \frac{1}{\frac{1}{N}\sum_{i=1}^{N} h_i} = \frac{1}{\bar{h}}. \tag{3}$$

In other words, the traffic intensity and the average time interval $\bar{h}$ between vehicles have a reciprocal relationship. Traffic intensity is usually given as the number of vehicles pass through section per hour. Intensity measurements can be performed at the intervals of varying duration. If a measurement duration is too short, this can lead to too high or low value when determining the peak traffic intensity, such as the intensity of traffic flows can vary considerably. In this regard, the Highway Capacity Manual recommends that intensity measurements be performed at 15-minute intervals.

The intensity of vehicle traffic is directly dependent on the capacity of the road section. Throughput is defined as the maximum number of vehicles or passengers that can pass through a facility per unit of time under normal prevailing conditions and with an acceptable level of safety.

The usual prevailing conditions (road conditions, traffic and traffic control) affect the throughput and must be uniform for each section to be analyzed.

DESCRIPTION OF THE RESEARCH METHODOLOGY

Input Data and Processing

For two years for each day in a given road point - regulated traffic light intersection observations and reported data have been made

- every 15 minutes for number of vehicles passing through this point;
- every 15 minutes for ambient temperature;
- every 15 minutes for atmospheric conditions;
- for seasonality;
- for workdays or holydays.

The input data for the number of vehicles passed are processed (Data Mining) and grouped by seasonality and then for each season by workdays and holydays. Data on the average ambient temperature and atmospheric conditions are also stored for each day.

Data sets shown in the scheme of Figure 1 are created.

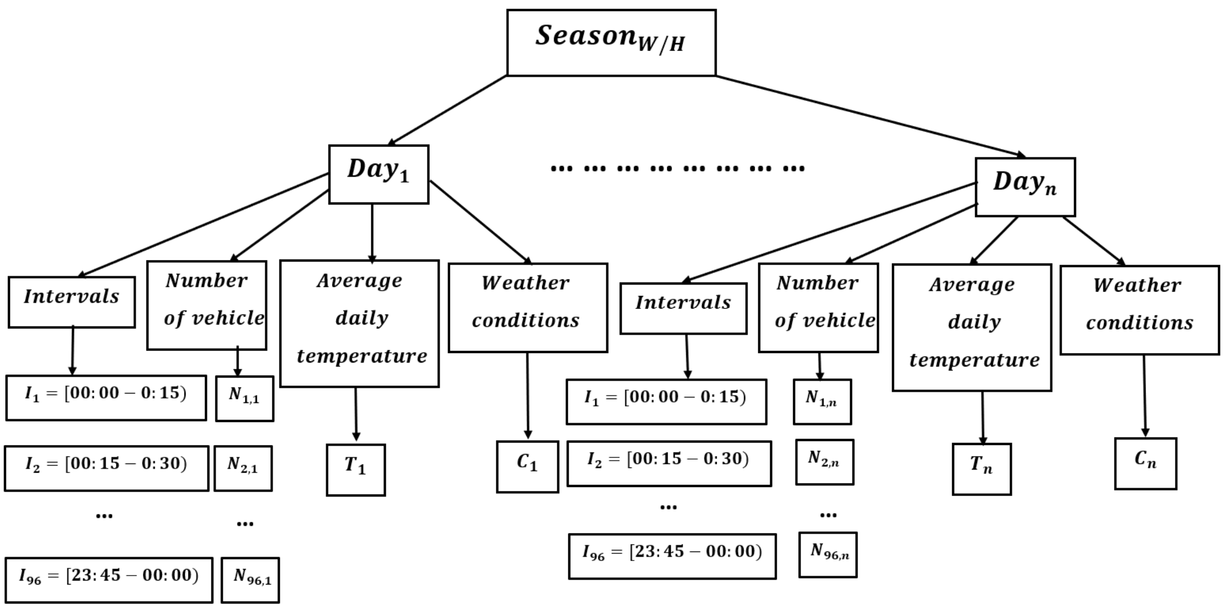

FIGURE 1. Scheme of the created data sets

For each interval $I_i, i = 1, \ldots, 96$, and for each season on workdays and holydays $Season_{W/H}$ an array of data is created from conditions that express the relationship between the influence of the average daily temperature, the weather conditions and the number of vehicles passing through the surveyed road point. The dependence is represented by the following matrix of conditions:

$$VC = \begin{pmatrix} V_1C_1 & V_1C_2 & \ldots & V_1C_L \\ V_2C_1 & V_2C_2 & \ldots & V_2C_L \\ \ldots & \ldots & \ldots & \ldots \\ V_RC_1 & V_RC_2 & \ldots & V_RC_L \end{pmatrix}, \quad (4)$$

where:

$V_r, r = 1, \ldots, R$, is a certain temperature range in which it is possible for the measured average daily temperature in a given interval;

$C_l, l = 1, \ldots, L,$, is a definite weather condition in a certain range.

For each of the conditions $V_lC_r, l = 1, \ldots, L; r = 1, \ldots, R$, at the respective studied time interval $I_i, i = 1, \ldots, 96$, and season $Season_{W/H}$ are found from the massif described in Figure 1, the days of this massif and the number of vehicles passing in front of the examined road point - Table 1.

TABLE 1. Input data for each of the conditions $V_l C_r, l = 1, \dots, L; r = 1, \dots, R$

Day	**Number of vehicle**	**Weigth**	
d_1	N_1	$w_1 = \frac{1}{\sum_{r=1}^{R} r}$	$N_1.w_1$
d_2	N_2	$w_2 = \frac{2}{\sum_{r=1}^{R} r}$	$N_2.w_2$
…	…	…	…
d_R	N_R	$w_R = \frac{R}{\sum_{r=1}^{R} r}$	$N_R.w_R$
		$\sum_{r=1}^{R} w_r = 1$	$\sum_{r=1}^{R} N_r.w_r$

Then vehicle traffic intensity prediction is:

$$N^* = \sum_{r=1}^{R} N_r.w_r. \tag{5}$$

The standard error in predicting traffic intensity is:

$$SD = \sqrt{\frac{\sum_{r=1}^{R} |N - N^*|^2}{R}}. \tag{6}$$

NUMERICAL REALIZATION

Input Numerical Data

Data for a key crossroads in the city of Sofia are used for the numerical realization – Tables 2÷4.

TABLE 2. Input numerical data for Numerical input data for one week from March 2018

	Workday	**Workday**	**Workday**	**Workday**	**Workday**	**Holiday**	**Holiday**
March 2018	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Av. daily temperature [^{0}C]	13.57	11.56	10.68	10.75	8.7	11.33	11.95
Weather conditions [scale 1-10]	6	5	4	4	2	4	5
Interval	**Number of vehicles passing through the surveyed road point / Intensity**						
[8:00-8:15)	257	259	249	261	265	196	187
[8:15-8:30)	263	268	257	267	272	201	197
[8:30-8:45)	298	304	297	286	290	212	203
[8:45-9:00)	326	345	352	337	356	223	207
[9:00-9:15)	378	395	378	392	386	236	215
[9:15-9:30)	402	435	424	431	412	244	236
[9:30-9:45)	397	402	392	386	399	256	238
[9:45-10:00)	388	376	371	367	358	263	242

TABLE 3. Input numerical data for Numerical input data for one week from July 2018

	Workday	Workday	Workday	Workday	Workday	Holiday	Holiday
July 2018	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Av. daily temperature [^{0}C]	20.49	21.02	22.89	23.73	24.03	25	24.64
Weather conditions [scale 1-10]	7	8	8	8	9	10	10
Interval	**Number of vehicles passing through the surveyed road point / Intensity**						
[8:00-8:15)	187	177	179	175	176	126	111
[8:15-8:30)	193	185	187	179	182	128	116
[8:30-8:45)	221	193	196	186	186	136	121
[8:45-9:00)	235	197	201	199	193	144	127
[9:00-9:15)	246	205	211	203	207	148	129
[9:15-9:30)	253	213	224	216	214	152	132
[9:30-9:45)	223	206	203	211	213	157	139
[9:45-10:00)	201	198	199	202	205	162	147

TABLE 4. Input numerical data for Numerical input data for one week from November 2018

	Workday	Workday	Workday	Workday	Workday	Holiday	Holiday
November 2018	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Av. daily temperature [^{0}C]	9.56	7.73	9.46	9.25	5.23	3.04	2.6
Weather conditions [scale 1-10]	6	5	6	6	5	4	3
Interval	**Number of vehicles passing through the surveyed road point / Intensity**						
[8:00-8:15)	263	271	264	269	272	188	162
[8:15-8:30)	275	276	277	276	278	197	171
[8:30-8:45)	303	294	289	293	302	202	178
[8:45-9:00)	325	308	305	321	317	205	189
[9:00-9:15)	372	372	366	358	338	208	206
[9:15-9:30)	405	426	428	399	412	212	209
[9:30-9:45)	399	412	404	397	394	223	217
[9:45-10:00)	387	406	392	375	387	245	222

Numerical Results

The numerical results of the study are presented in Tables 5÷7 and Figure 2÷4.

TABLE 5. Numerical results for forecasting intensity for 12-18 March 2018

	Workday	Workday	Workday	Workday	Workday	Holiday	Holiday
March 2018	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Av. daily temperature [^{0}C]	13.6	11.72	10.23	10.2	8.8	11.2	12
Weather conditions [scale 1-10]	6	5	4	4	3	4	4
Interval	**Number of vehicles passing through the surveyed road point / Intensity**						
[8:00-8:15)	267	266	256	272	266	192	190
[8:15-8:30)	274	268	267	279	279	198	199
[8:30-8:45)	296	303	298	288	301	205	202
[8:45-9:00)	332	351	360	335	364	217	205
[9:00-9:15)	381	396	379	388	382	231	216
[9:15-9:30)	407	426	431	430	419	239	229
[9:30-9:45)	392	393	404	382	402	258	238
[9:45-10:00)	381	375	370	361	355	263	245

TABLE 6. Numerical results for forecasting intensity for 9-15 July 2018

	Workday	Workday	Workday	Workday	Workday	Holiday	Holiday
July 2018	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Av. daily temperature [^{0}C]	21.1	21.5	23.2	23.5	24.5	25.5	24.3
Weather conditions [scale 1-10]	8	8	8	9	9	10	10
Interval	**Number of vehicles passing through the surveyed road point / Intensity**						
[8:00-8:15)	179	176	182	170	169	119	117
[8:15-8:30)	188	181	195	182	178	129	121
[8:30-8:45)	219	191	200	192	185	139	129
[8:45-9:00)	228	205	206	203	199	142	133
[9:00-9:15)	248	209	219	204	210	151	135
[9:15-9:30)	255	207	229	219	218	156	142
[9:30-9:45)	219	202	194	206	211	162	148
[9:45-10:00)	206	199	186	191	194	173	150

TABLE 7. Numerical results for forecasting intensity for 12-18 November 2018

	Workday	Workday	Workday	Workday	Workday	Holiday	Holiday
November 2018	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Av. daily temperature [^{0}C]	10.2	7.5	9.7	9.2	4.9	2.9	2.5
Weather conditions [scale 1-10]	6	4	5	5	5	3	3
Interval	**Number of vehicles passing through the surveyed road point / Intensity**						
[8:00-8:15)	269	272	265	270	266	184	170
[8:15-8:30)	281	285	278	273	279	201	175
[8:30-8:45)	309	296	295	301	309	209	177
[8:45-9:00)	317	310	210	327	321	215	195
[9:00-9:15)	368	359	254	357	335	217	207
[9:15-9:30)	404	427	417	406	419	219	213
[9:30-9:45)	395	411	402	398	396	224	216
[9:45-10:00)	388	405	401	379	388	239	229

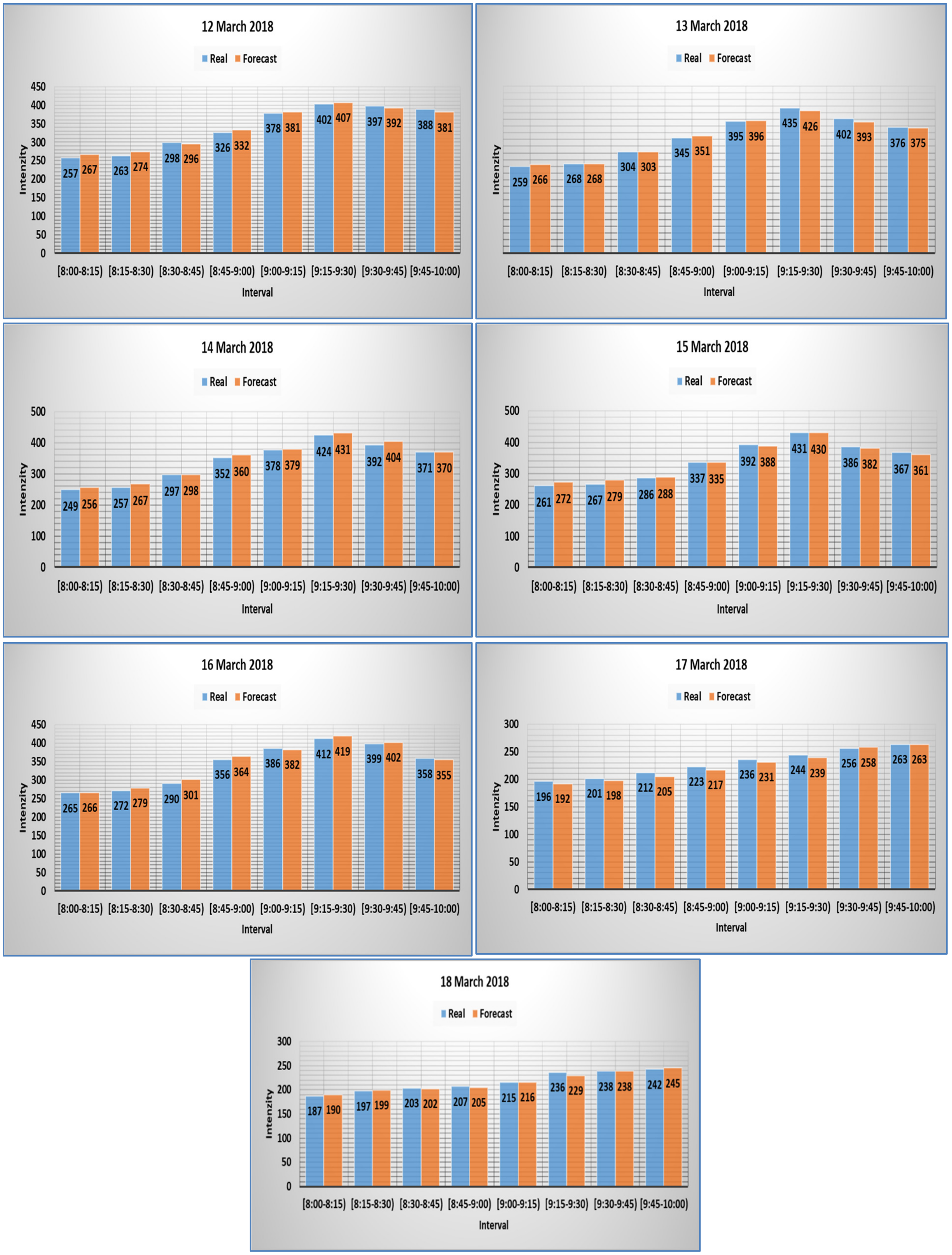

FIGURE 2. Numerical results for forecasting intensity for 12-18 March 2018, $SD = 0.65\%$

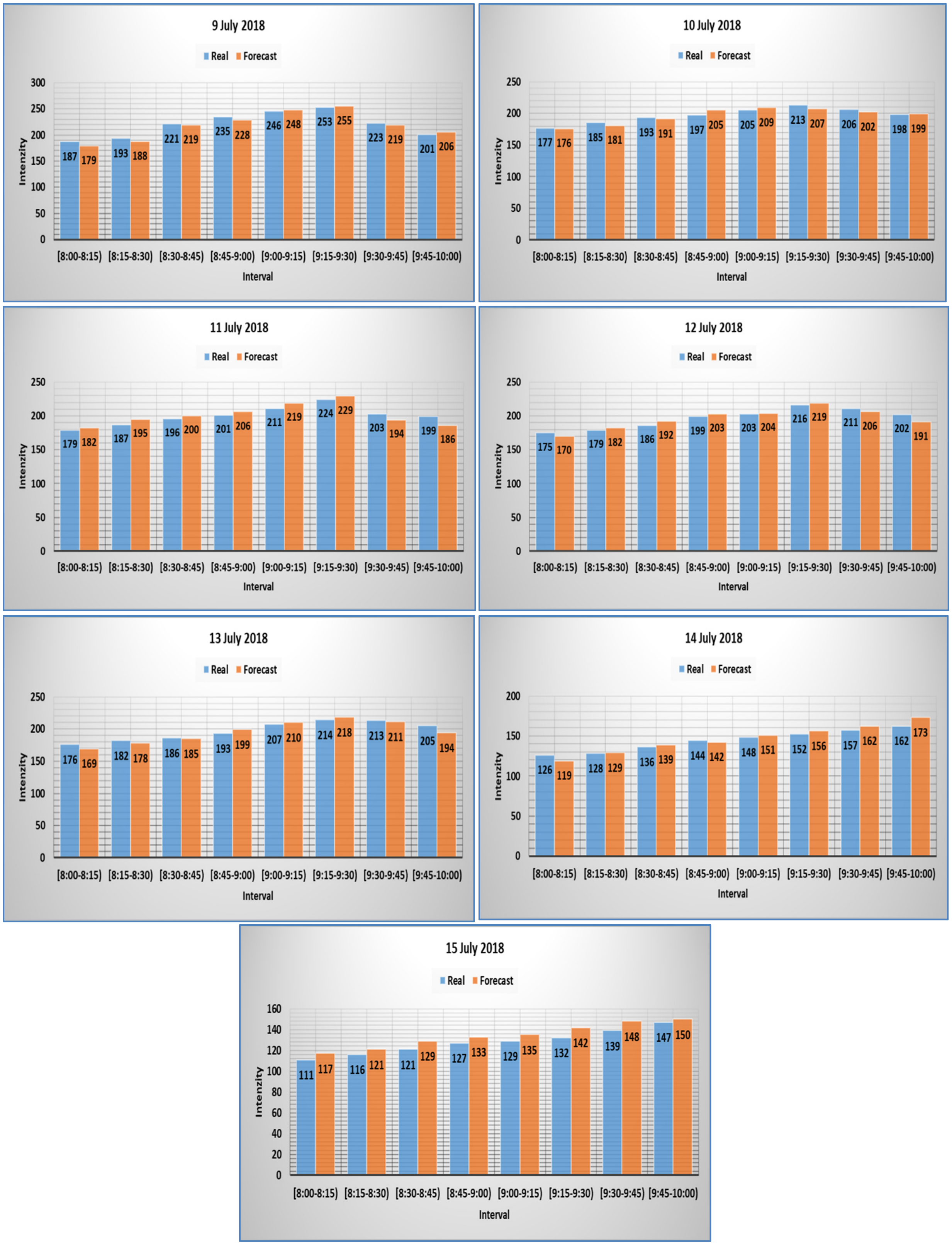

FIGURE 3. Numerical results for forecasting intensity for 9-15 July 2018, $SD = 0.36\%$

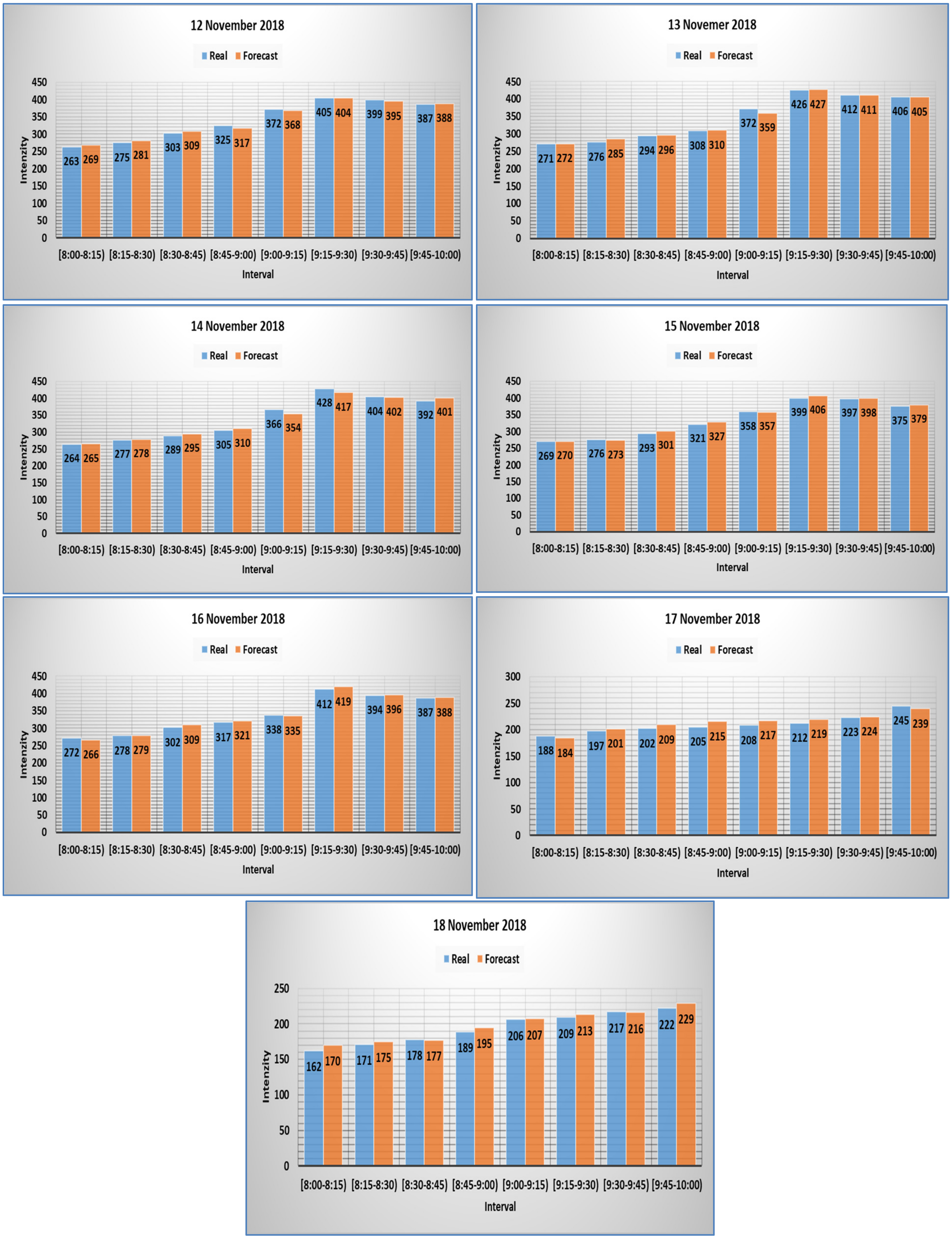

FIGURE 4. Numerical results for forecasting intensity for 12-18 November 2018, $SD = 0.66\%$

The numerical realization is made in the programming environments of Python, MatLab, MS Excel.

Discussion of Numerical Results

The following conclusions can be obtained from the numerical results:

- The proposed methodology in this study, including processing of input data (Data Mining), statistical and stochastic methods, gives very good results in forecasting the intensity of traffic at a main intersection. This is evident from the estimate of the error, which is below 1%. Also, this is due to the appropriate choice of factors that directly affect the studied process and their parameters.

- The magnitude of the intensity (as can be seen from the obtained numerical results) depends mainly on: the intervals of the day whether they are peak or not; working or weekend days; seasonality; the average daily temperature; meteorological conditions.

CONCLUSION AND FUTURE WORK

The present study is a kind of research of the intensity of traffic in front of a road point, which is monitored at the same time and its capacity. Work can be done from now on to increase throughput, but this will be the subject of our further research related to intelligent traffic management. This makes the present study significant in substance.

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