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EARLY 2015 PERFORMANCE IN BALTIC SEA PORTS: FORECASTS OF ESTONIAN PERFORMANCE FOR ENTIRE YEAR

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Many changes have appeared in year 2015. In Europe economic malaise has continued since debt crisis started in year 2010, and although its effects on Northern Europe have started to diminish, new economic dark clouds have appeared through sanctions set by both European Union and Russia to each other during year 2014. Together with these, shipping sector has been under pressure due to strict sulphur regulation implemented from early 2015 onwards in the entire Baltic Sea Region. Due to these factors, sea ports at Baltic Sea have been under pressure during the first months of 2015, this particularly concerning container handling. Based on our regression model forecast, Estonia and Port of Tallinn shall have clearly declining container handling year ahead. However, overall handling at sea port is not so easy to forecast.

Keywords: Baltic Sea, crisis, sea ports, handling, TEU

1. Introduction

Development of economies after global financial credit crunch (years 2008-2009) has been rather difficult to all North European countries (e.g. Baltic States, see (Hilmola, 2013)). This global economic downturn was followed by debt crunch of Southern Europe, which has had its effects on local economies and logistics sector development since 2010. On a top of these, transportation, and particularly sea transportation sector, have been under tremendous environmental regulation process in Baltic Sea Region. In year 2010 as first in the world sulphur content of diesel at Baltic Sea was lowered to 1.0 %, which was continued with stiff decline to 0.1 % level in year 2015 (Notteboom, 2011; IMO, 2015; Hilmola, 2015). This has lead to higher fuel costs for ships and a somewhat higher freight rates. Under horizon is also nitrogen ban on ships (Corbett et al., 1999), which has now been postponed for some years (Helcom, 2014). Together with this CO_2 emissions of shipping are closely followed and some actions or payment systems are to be expected to be implemented in the future (Ellerman et al., 2010; Stead, 2006).

On positive side, Baltic Sea Region has been surrounded by two powerful economies, those of Germany and Russia. In addition, Poland has received increasing amount of greenfield investments on manufacturing sector (UNCTAD, 2014). However, these positive developments have been constrained since year 2014 as political dispute between Russia and European Union developed. Together with EU, sanctions have been supported by USA. Sanctions and trade limitations have been implemented in both directions – especially in Baltic Sea Region and analyzed countries of this research have been hit hard by Russian ban to import of food and food products from EU. Sanctions have resulted on declining trade and this inevitably has its effects on logistics sector, and sea ports. It should be reminded that sea ports are not small issue for analyzed local economies of this research work. Situation even without sanctions is not easy for transportation chains – numerous basic problems remain between EU countries and CIS, and entire transportation chain is not even wanted to be managed by single body (Bazaras et al., 2015). However, in long-term eastern Baltic Sea countries have completed significant changes and investments (e.g. early situation, see (Buchhofer, 1995; Ország-Land, 2000), and act now as major connecting area between east and west (Hilmola, 2011).

They offer a reasonably high amount of work for local people, and typically salary level is higher than in other sectors. For example in Estonian logistics sector involved directly 33 000 employees and indirectly 49 000 employees (accounts 7.84% of all employees). In Estonia the total estimated number of employees in 2014 was 625 000 (Statistics Estonia, 2015). The transit sector employs 8000 employees (Tender and Kalmer, 2013).

In addition, maintenance and investments on sea port handling capacity and supporting infrastructure is important issue from economic side. Together with these, material handling at ports supports e.g. hinterland transportation as freight flows at railways are key for railway sector infrastructure maintenance funds (Thompson, 2008). Passenger transport is enabled in number of countries too, due to sea ports and their freight flows (in such countries like Russia, Estonia, Latvia and Lithuania, also in parts in Poland; see e.g. from case of Russia annual results of (RZD, 2012; Baltic Course, 2015)). Crisis in 2008-2009 showed that logistics sector has far wider implications on local economies than could be imagined in the first place (Hilmola, 2013; Sakiene, 2011).

Motivation of our research work is the greatly changing business environment at sea transports during year 2015. Earlier nearly all analyzed sea ports were on constant growth track, and actually 2008-2009 economic crisis was only contemporary phenomenon, which was surpassed in few years. This not only concerns Russia, but also the Polish sea port of this study and all Baltic States sea ports. Only in Finland volume growth has been extremely sluggish e.g. in containers and real recovery from the 2008-2009 crisis still waits to come. Therefore, this new environment is worth to analyze in light of changes of early 2015, and available early year data of sea port handling. Research questions to be answered in this study are following ones: (1) 'How have demand developed overall and in containers being handled?', and (2) 'Could early months be used as proxy for entire year performance?'

This research is structured as follows: In Section 2 is being analyzed sea port handling performance of most important sea ports of Baltic Sea concerning Poland, Lithuania, Latvia, Estonia, Russia and Finland. For all of these countries sea ports hold high importance due to the distance to Central Europe. This analysis is followed by regression forecast models developed in Section 3 concerning port of Tallinn and its overall sea port handling and container throughput. Final Section 4 concludes our work, where we also propose further research avenues.

2. Analysis of Sea Port Performance in January-February 2015

Overall Baltic Sea ports have done well as compared, what is the macro economic environment (resulting on sluggish demand or declining one) and the new environmental demands set by sulphur directive (cost increase). As Table 1 illustrates, growth has continued in Gdansk, Klaipeda and Riga. Also some Russian sea ports have done well such as Ust-Luga and Primorsk. However, it should be noted that latter one was having declining volumes in year 2014, and therefore it is relatively easy for it to show growth in year 2015. In Finnish and Estonian sea ports situation is inconsistent. Port of Helsinki shows moderate growth as port of HaminaKotka in turn records similar decline. Port of Tallinn is in significant decline; situation is the same in the port of Ventspils.

As many sea ports in Table 1 are handling a lot of oil and raw materials, was analysis completed regarding to sub-cargo groups. It was interesting to note that in general, growth is supported by handling of raw materials. For example, in Ust-Luga growth could be explained with oil and oil products as well as coal related raw materials handling. In Primorsk single handled cargo group is oil, which is in somewhat growing track. In Kaliningrad wheat and sugar handling together with roro cargo cause it. Riga is still growing with dry bulk, namely coal. Fertilizers and liquids have been the strength of Klaipeda. Fertilizers cargo flow also supported by Belarus. The state is the world biggest supplier of potassium mineral fertilizers. Belarus also is using Port of Klaipeda container terminals as gateway for import of the consumer goods. By estimation totally up to 125 000 containers in a year are transported from Port of Klaipeda to Belarus by truck. Situation is similar with Gdansk, where dry bulk and liquids have supported volumes. Only in Helsinki container and roro cargo handling, not that significantly raw materials, enable its moderate growth.

Table 1. Cargo handled in different Baltic Sea Ports during January-February 2015 ('000 tons). Sources (data): (Baltic Sea Ports, 2015)

Country	Sea Port	Tons	Change
Finland	Helsinki	1764.0	5.1 %
	HaminaKotka	2230.1	-4.0 %
Russia	Ust-Luga	13454.4	23.8 %
St. Petersburg	City Sea Port	8099.6	-7.6 %
	Primorsk	9890.1	7.6 %
	Kaliningrad	2191.7	4.1 %
Estonia	Tallinn	4349.1	-19.1 %
Latvia	Riga	6834.1	4.7 %
	Ventspils	4827.0	-18.3 %
Lithuania	Klaipeda	5959.5	9.0 %
Poland	Gdansk	5225.9	4.5 %

In Table 1 sea ports showing higher volume drops are Tallinn and Ventspils. In both of these, cause of decline is mostly explained with raw materials, and that of liquids (oil and oil products; biggest volume group). Also in Tallinn other product groups have declined such as container handling. In Ventspils all reported cargo groups are in somewhat declining path. HaminaKotka shows minor decline, which is mostly caused due to the dynamics of forest industry. Imports of wood to HaminaKotka declined as did the exports of some forest industry end products together with unitized export cargo.

Table 2. Containers handled in different Baltic Sea Ports during January-February 2015 (in TEUs). Sources (data): (Baltic Sea Ports, 2015)

Country	Sea Port	TEUs	Change
Finland	Helsinki	64298	3.2 %
	HaminaKotka	94795	-8.4 %
Russia	Ust-Luga	15098	-11.8 %
St. Petersburg	City Sea Port	273293	-28.8 %
	Primorsk	N/A	
	Kaliningrad	25299	-53.2 %
Estonia	Tallinn	34462	-13.9 %
Latvia	Riga	63167	3.0 %
	Ventspils	N/A	
Lithuania	Klaipeda	65620	-7.3 %
Poland	Gdansk	169509	-17.2 %

What is interesting under the handling volume surface, is the consistent and significant container handling decline in nearly all analyzed sea ports (except Helsinki and Riga). This is illustrated in Table 2. Typically container cargo does not play importance in overall handling as in tons it can not match volumes of e.g. oil and coal (if sea port handles these too). All Russian sea ports show very significant declines, where it is most alarming the development of city sea port of St. Petersburg; in relative terms drop has been 28.8 %, but volume wise it is 110,763 TEU containers. Elsewhere declines are also significant in relative terms, but in volume, only Kaliningrad (28,746 TEU handling decline) and Gdansk (35,249 TEU drop) are showing tens of thousands of handling volume decline. In HaminaKotka, Ust-Luga and Tallinn declines are some thousands of containers, but not higher than nine thousand containers.

In the future, the Baltic Sea container transport market depends to a greater extent on Russia's economic situation and its fluctuations. By today, also container penetration in Russia remains fundamentally low. In Russia production level of consumer goods for retail customers is also low. In practice, ports of all the other countries are competing for Russia-directed transit container flows, for prospective growths are the highest there. It is important to note a positive fact that the majority of Russia's total container flow is transported through the Baltic Sea. More than 80 % of leading container terminal operator in Russia, Global Ports, and its container handling capacity is serving Baltic Sea (Global Ports, 2015).

In overall, it could be said that sea port handling situation in tons is not that extremely bad in Baltic Sea ports, but there are exceptions, and situation is not consistent in group of analyzed sea ports. Volumes are supported by raw materials (liquid and dry bulk), and ports mastering these product groups, are strong also in overall. What is interesting in geographical terms, is the fact that all declining handling volume (tons) ports are located at the level of Ventspils or above. From this it could be at least speculated that environmental demands of sulphur regulation have in parts hurt these longer distance sea ports (to Central Europe, main markets and sea ports), where cargo is needs to proceed longer distance Baltic Sea route and this completed with expensive sulphur free oil. General world trade situation is reflected in port handling of containers, where huge declines have been recorded. These declines could also be explained with sulphur regulation as increasing sea freights prevent or constrain somewhat trade volume of import and export. Under the surface situation is not good, and if situation remains such, it means major problems for economies of the region (as container handling is so tightly tied to economic growth in the Baltic Sea region and in the world).

3. Using Two First Months to Forecast Entire Year 2015 Performance in the Port of Tallinn

It could be argued that analyzing entire year and ongoing change at Baltic Sea is invalid with such short amount of data, only two months. We tried this with one port data, concerning Tallinn. Overall availability was from period of 1999-2014, where both total tons handled (Figure 1) and total TEU container amount (Figure 2) were analyzed. This period is sufficient to cover numerous economic crises and disturbances as amount of data points are 16. Only potential conflict in here is with TEU container handling amounts, which have been low in early 2000 in Tallinn. Measured in tons, Port of Tallinn has been significant during the entire observation period.

As Figure 1 illustrates, for total tons handled in a year, two first months are not good proxy. However, it is not poor either. Situation is satisfactory as R^2 value of simple linear regression model is 46.16 %. This means that two first months explain this percentage amount from entire year of port handling. We also did run detailed regression analysis for this relationship, and found that both co-efficient and fixed term in the regression model were statistically significant. Model is having considerable downside in the forecast variation, as standard error is 3590.16 thousand tons. Based on this model forecast for Tallinn concerning year 2015 handling at sea port is just below 30 mill. tons. However, this is under uncertainty due to standard error, and could be easily 3-7 mill. tons wrong (both directions, up or down). Therefore, it is difficult to say whether handling amounts will decline in year 2015. Actually current forecast gives even slight growth as compared to year 2014. This is all because forecast precision is so low and standard error in turn high.

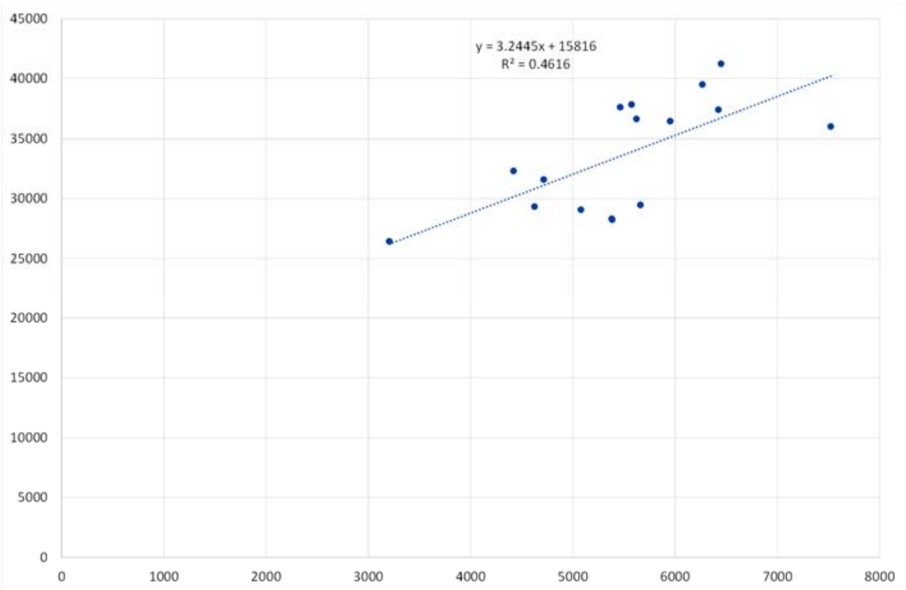

Figure 1. Scatter gram of forecasting entire year of handling (‘000 tons, y-axis) with two first months of handling (‘000 tons, x-axis) in port of Tallinn, Estonia during time period of 1999-2013. Source (data): Port of Tallinn (2015)

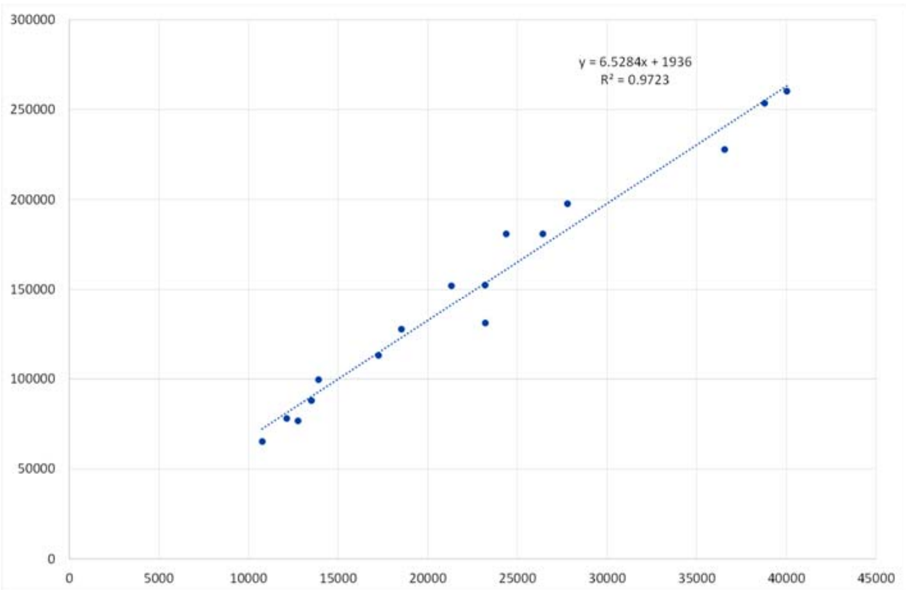

Figure 2. Scatter gram of forecasting entire year of container handling (TEUs, y-axis) with two first months of handling (TEUs, x-axis) in port of Tallinn, Estonia during time period of 1999-2013. Source (data): Port of Tallinn (2015)

For containers scatter gram and following regression line is producing much better forecast (Figure 2). First two months seem to produce rather consistent view from the entire year and as could be noted, variation among regression line is rather low. If R^2 value is analyzed, we may note that proposed regression model forecasts 97.23 % from annual container handling volume. This value is extremely high. However, as we analyzed regression model through statistical analysis, we found that fixed term in Figure 2 linear model was not statistically significant. Co-efficient of Figure 2 was of course statistically significant with extremely high level. This means that regression line should be without fixed term (in Figure 2 this fixed term is 1936). As fixed term was abandoned and regression line was forced to start from zero, then regression model co-efficient was 6.602 and it was able alone to forecast 99.6 % from annual volume with two first months. Standard error of this model is 10508.84 TEU containers (per year). Based on this regression model we could with confidence forecast that year 2015 will be year of decline for Port of Tallinn in container handling. Regression model will forecast actual amount to be 227,519.3 TEUs. This is 12.6 % lower than in year 2014. Even if standard error is taken three times and added to this average handling amount of forecast for year 2015, it could be concluded that year will have lower performance than earlier one. Change does not seem to be extremely significant, but it is first year of decline since year 2009. This year 2014 decline seems to be in the magnitude half from this big drop experienced during global credit crunch.

4. Conclusions

Logistics flows and sea ports are important for analyzed countries, not only to support local and regional economies, but also due to their direct effects on employment, income and profits. Especially in all Baltic States logistics sector is huge and important employer. Therefore, its development receives attention and especially negative changes influence local economies in major scale. One example is hinterland transports, which is typically accomplished by railway in case of raw materials. Freight at rails pays one of the highest railway access fees in Europe in all Baltic States, and enables the maintenance of rail network as well as passenger traffic. If freight volumes decline by 10-20 % in one year, it means significant budget problems for railway sector. Similar kind of effect does not only concern Baltic States, but is also concern in Russia. Freight and key industrial product groups have become extremely critical for the countries in concern.

Sea ports have done relatively well (as compared to macro economic environment) during early months of year 2015. This with some exceptions such as Tallinn and Ventspils. Tons handled in the studied sea ports depends greatly on raw material handling, and mostly on oil, oil products, coal and fertilizers. Even if these markets have experienced price declines (end products) lately, it has not affected demand. It seems that demand for these products has sustained rather well in the region (these critical raw materials typically end in European Union member countries). However, as a word of caution remains very low performance on container handling. This is merely connected to local warehousing and value adding logistics sectors, which will bear these effects in their operations. If container handling is about to decline 10-30 % in year 2015, it means another really difficult year for logistics sector companies.

Second part of our empirical analysis concerns the effect of two first months on entire year performance of sea port. In the regression models was used data available from Port of Tallinn. Our analysis showed that two first months have role in both overall tons and containers handled. However, another question remains, whether these models are useful ones. Developed total handling model was having such high standard error in it that forecast for year 2015 overall handling was not accurate enough. Volumes could even increase in this year, as based on the model, even if first two months have been difficult ones. However, container handling model was much higher in accuracy and argued that container volumes in Tallinn will drop in year 2015. This decline will be significant, but not as big as it was in year 2009.

As a further research, we would be interested to develop models for all sea ports using early information of particular year. In this research work, we used first two months, but observation period could be extended to three and four early months too. This extension could increase the accuracy of forecast. Interest should not only be overall handling in tons or sea containers, but also other cargo groups should be taken into consideration. In e.g. all Baltic States sea ports one raw material group is critical over the other, in Tallinn it is oil and oil products, in Riga it is coal and in Lithuania it is fertilizers. It is not only the interest of sea port to develop these models, but incorporated parties should involve local government and railway sector too.

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MIXED VEHICLE FLOW AT SIGNALIZED INTERSECTION: MARKOV CHAIN ANALYSIS

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We assume that a Poisson flow of vehicles arrives at isolated signalized intersection, and each vehicle, independently of others, represents a random number X of passenger car units (PCU's). We analyze numerically the stationary distribution of the queue process $\{Zn\}$, where Zn is the number of PCU's in a queue at the beginning of the n-th red phase, $n \to \infty$. We approximate the number Y_n of PCU's arriving during one red-green cycle by a two-parameter Negative Binomial Distribution (NBD). The well-known fact is that $\{Zn\}$ follow an infinite-state Markov chain. We approximate its stationary distribution using a finite-state Markov chain. We show numerically that there is a strong dependence of the mean queue length $E[Zn]$ in equilibrium on the input distribution of Y_n and, in particular, on the "over dispersion" parameter $\gamma = Var[Y_n]/E[Y_n]$. For Poisson input, $\gamma = 1$. $\gamma > 1$ indicates presence of heavy-tailed input. In reality it means that a relatively large "portion" of PCU's, considerably exceeding the average, may arrive with high probability during one red-green cycle. Empirical formulas are presented for an accurate estimation of mean queue length as a function of load and g of the input flow. Using the Markov chain technique, we analyze the mean "virtual" delay time for a car which always arrives at the beginning of the red phase.

Keywords: signalized traffic light, Markov chain, average queue length, mixed vehicle input flow, negative binomial distribution, over dispersed input, virtual delay

1. Introduction. Model Description

We consider one-lane vehicle flow arriving at a signalized intersection working in periodic regime. One cycle consists of a green phase of duration T_g followed by a red phase of duration T_r. We will use index n to denote the n-th working cycle, $n = 1, 2, \ldots$. Let X_n be the number of *vehicles* arriving at the intersection during the n-th cycle.

It will be assumed that $\{X_n\}$, ($n = 1, 2, \ldots,$) is a sequence of independent identically distributed random variables (r.v.'s) following the Poisson distribution with parameter Λ. Contrary to the standard assumption about the input flow, we assume that vehicles *differ* in their geometric parameters, so that from the traffic load point of view they represent different numbers of PCU's (passenger car units). For example, the text (Slinn et al., 2005, 102) gives the following data:

Vehicle type	PCU
Cars and light goods vehicles	1
Medium goods vehicles	1.5
Buses and coaches	2.0
Heavy goods vehicles	2.3

More formally, it will be assumed that the i-th vehicle, independently of other vehicles in the input flow, represents V_i PCU's, and

$$P(V_i = w_j) = p_j, \quad j = 1, \ldots, k. \tag{1}$$

If, for example, 80% of all vehicles are passenger cars, 10% - buses, and the rest - heavy goods vehicles, then $w_1 = 1$, $w_2 = 2$, $w_3 = 2.3$, and $p_1 = 0.8$, $p_2 = 0.1$, $p_3 = 0.1$.

Now the number of PCU's arriving at the intersection during n-th traffic light cycle is represented as

$$Y_n = V_1 + V_2 + \ldots + V_{Xn}, \tag{2}$$

i.e. as a sum of random number of random variables. It is assumed that the r.v.'s X_n and V_i are independent.

The standard Poisson input flow of cars is a particular case of (2) if $P(V_i = 1) = 1$, i.e. if each vehicle represents one PCU.

Random variable Y (we will omit the cycle index j) has a compound Poisson distribution, see Feller (1963), Chapter 12. Its mean value equals

$$E[Y] = E[V_i] \cdot E[X] = E[V_i] \cdot \Lambda. \tag{3}$$

It is assumed that during the green phase, the intersection can serve the maximal number m of PCU's and that the intersection works in *stationary* (underflow) regime for which the load

$$\rho = \frac{E[Y]}{m} < 1\,. \tag{4}$$

Our main goal is to analyze the number of PCU's Z_n waiting in line at the beginning of red phase in the n-th cycle. The case that all vehicles in the input flow represent one PCU (one car) was investigated by Newell (1960) in his classic work. He postulated the following principal relationship between Z_{n+1} and Z_n:

$$Z_{n+1} = \max[Z_n + Y_{n+1} - m,\ 0]. \tag{5}$$

This formula means the following: if the number of cars left unserved from the previous cycle Z_n plus the number of cars Y_{n+1} arrived at the intersection during the present cycle (*no matter what the exact arrival times were*) is $\geq m$, the number of cars passed through the intersection will be m . Thus the number of cars in queue at the beginning next red phase will be Z_{n+1} according to (5). The importance of (5) lies in the fact that it establishes that the sequence of r.v.'s $\{Z_n\}$, $\{n = 1, 2, 3, \ldots\}$ creates a Markov chain. This fact is crucial to the theoretical and numerical investigation of the queue length in equilibrium.

Two complications arise when we are dealing with the input flow of vehicles having *different* number of PCU's. The first one is that now Y_n are not always integer-valued. If, for example, 8 "regular" cars, one bus and one light good truck arrive during one cycle, the number of PCU's will be 10.5.

The second one is that the maximal number of m PCU 's not always can be implemented. Imagine, that in the above example the bus (2 PCU's) is the last vehicle approaching the intersection during the green phase. Depending on its driver's habit, the bus may start moving across the intersection even if in the middle of its movement the light will change to red. In this way the intersection provides an extra service capacity of about one PCU. On the contrary, the more hesitant driver would not start moving across the intersection, leaving one time interval of length $\delta = Tg/m$ unused. We decided to ignore the second complication by assuming that in the long run, the "under use" and "over use" of maximal capacity m compensate each other.

As to the first complication, we assume that the actual number of PCU's in one cycle can be rounded to the nearest integer. So, for example, if $X_n \in [9.5,\ 10.5)$, we put $X_n = 10$. If the round-off error is uniformly distributed in the interval $[-0.5,\ 0.5]$, the average error e of the round-off by its absolute value is equal 0.25; for a triangular distribution of the error $e = 0.33$. In our opinion, it can be neglected if the average number of PCU's per cycle is about 8-12. Besides, only a part of all cycles have non integer values of PCU's.

In this paper, our task is calculating the mean number of PCU's Q waiting in the queue at the beginning of red light. As a rule, the calculation of the mean delay at the traffic light demands the knowledge of Q, see, e.g. the works of Newell (1960, 1965), McNeill (1968), Darroch (1963), Miller (1963), and Webster (1958). As a rule, these works take into account also the variability of the input flow by introducing the "over-dispersion" parameter $\gamma = Var[Y]/E[Y]$.

The further exposition will be as follows. In Section 2 we investigate the variance of r.v.'s Y_n and discuss the possibility to approximate their distribution by the Negative Binomial (NBD). Its important property is that it allows to describe the input flow for the so-called over dispersed case of $\gamma > 1$. NBD is a "heavy-tailed" distribution comparing to Poisson. In Section 3 we investigate numerically the stationary distribution of Z_n by means of Markov chain technique and present the queue parameters for various loads and the Poisson input flow of vehicles. In Section 4 we present numerical results for a collection of input flows, for various loads ρ and various degrees of "over dispersion" γ and compare the queue parameters with the Poisson input flow. We demonstrate that "over dispersed" input flow considerably increases the queue length and, therefore, the delay time. In Section 5 we introduce the notion of *virtual delay* time and present formulas and numerical results for its mean and variance for various input flows. The appendix contains a collection of empirical formulas expressing the mean queue length as a function of ρ and γ and compares them to Miller's approximation (1963).

2. Variance of Y_n. Negative Binomial Distri- bution (NBD)

By the result of (Feller, 1963), Chapter 12, Section 6,

$$Var[Y] = E[X] \cdot Var[V] + Var[X] \cdot E^2[V] = \Lambda \cdot E[V^2]. \quad (6)$$

Comparing with (3), we see that

$$Var[Y]/E[Y] = E[V^2]/E[V] > 1, \quad (7)$$

while for "regular" Poisson input flow this ratio equals 1. It has been noticed already in the early traffic investigations (Darroch, 1963; Miller, 1963; Webster, 1958) that over dispersion considerably increases the car delay time at the intersection.

In the above example of mixed flow with 10% of buses and 10% of heavy goods vehicles,

$$E[V^2] = 1 \cdot 0.8 + 2^2 \cdot 0.1 + 2.3^2 \cdot 0.1 \approx 1.53,$$

which is a rather large increase in variability of the number of PCU's per cycle compared to the Poisson flow.

To carry out the further investigation of the Markov process $\{Z_n\}$ we must have an analytic form of distribution of Y_n. In statistical practice, the so-called Negative Binomial distribution (NBD) is considered a suitable candidate for an over dispersed distribution. Its probability mass function has the following form:

$$g(k)=[Gamma(k+r)/Gamma(r)k!](1-p)^k p^r \quad (8)$$

for k=0,1,2,…

Table 1: Fitting NBD to Mixed Input Flow. $\Lambda = 10$

No/PCU	$w_1 = 1$	$w_2 = 2$	$w_3 = 3$	$w_4 = 4$	r	p	γ	X^2
1	0.7	0.25	0.05		16.2	0.54	1.8	25.3
2	0.8	0.15	0.05		17.6	0.58	1.7	25.9
3	0.9	0.075	0.025		27.5	0.71	1.4	12.2
4	0.95	0.025	0.025		36.2	0.77	1.3	20.6
5	0.95	0.025	0.02	0.005	31.2	0.74	1.3	26.7
6	**0.9**	0	0	**0.1**	8.41	0.39	**2.54**	**39.7**
7	0.9		0.1		15.0	0.56	1.8	28.5
8	0.9	0.1			41.7	0.79	1.3	21.2

Here r is a real nonnegative parameter, and $p \in (0, 1)$. For $r \to \infty$, NBD approaches Poisson distribution.

Two central moments of the NBD, mean μ and variance Var, are expressed via parameters p, r as follows:

$$\mu = r(1-p)/p, \quad Var = \mu(1 + \mu/r). \quad (9)$$

There is only one situation where the Poisson sum of integer-valued r.v.'s exactly follow the NBD. This is the case when the random summands have so-called *discrete logarithmic distribution*, with probability mass function $f_n = C \cdot a^n/n$, $n = 1, 2, \ldots$, see (Feller, 1963), Chapter 12. Unfortunately, this distribution does not describe well the distribution of PCU's in a single vehicle.

Our further analysis of the mixed input flow is based on the following assumption: the total number of PCU's in the vehicles arriving during one cycle (after round-off as described above) can be approximated by an NBD having the same two central moments, i.e. the same mean and variance. In other words, we assume that the distribution of Y_n approximately follows the NBD. We remind that Y_n and Z_n represent now not the number of vehicles, but the number of PCU's arriving during one cycle at the traffic light and the number of PCU's waiting in queue at the beginning of red light, respectively.

Table 1 presents a series of eight simulation results, each based on 500 independent replicas of simulated r.v.'s Y_n. Each replica represents an observed value of the total number of PCU's in X arriving vehicles, where X is a Poisson r.v. with mean $\Lambda = 10$.

Columns 2-5 present the probabilities of having $w_1, \ldots, w_4$ PCU's in one vehicle. For example, in case No 3, 90% of all vehicles are passenger cars (1 PCU), 7.5% have – two and 2.5% - three PCU's. $r = 27.5$ and $p = 0.71$ are the parameters of the NBD obtained by fitting the mean and variance of Y_n to the mean and variance of the NBD. In this example, the "over dispersion" parameter $\gamma = Var[Y]/E[Y]$ is 1.4.

The last column is the observed value of the chi-square statistic. In our experiment, we worked with 30 frequencies united into 22 groups, which corresponds to 21 degrees of freedom. The critical values are $\chi^2_{0.2} = 26.2,\ \chi^2_{0.1} = 29.6,\ \chi^2_{0.05} = 32.7.$ We see, therefore, that in all cases except the case No 6, we observe an excellent fit. The tendency is that the quality of the fit decreases when the number of PCU's becomes more dispersed. Physically, it happens with the increase of the percentage of very long vehicles. So, in case 6 we have a bad fit because of a relatively large percentage of very long vehicles with $w_4 = 4$, which results in $\gamma = 2.54$, much higher than in other cases.

3. Stationary Distribution of $\{Zn\}$

The Markov chain of eqn (5) has an infinite one-step transition matrix $\mathbf{P} = ||p_{i,j}||,\ i, j = 0, 1, 2, \ldots,$, where $p_{i,j} = P(Z_{n+1} = j|Z_n = i)$. We remind that Z_n is the number of PCU's in the line at the beginning of the n-th red light phase.

Let us determine the elements of $\mathbf{P}$. Denote by $G(k) = P(Y \le k),\ g(k) = P(Y = k),\ k \ge 0,\ g(k) = 0$ for $k < 0$. (Here index n is omitted for the r.v.'s Y_n.) The elements of matrix $\mathbf{P}$ depend on m and on the discrete density $g(k)$:

$$p_{i,0} = G(m - i),\ i = 0, 2., \ldots, m;\ p(i, 0) = 0, \text{ if } i > m; \tag{10}$$

$$p_{i,j} = g(m + j - i), \text{ for } i = 0, 1, 2, \ldots, j > 0.$$

For example, suppose that $m = 5,\ i = 6,\ j = 1$, i.e. $Z_n = 6,\ Z_{n+1} = 1$. This happens if and only if no new cars arrive during the cycle, i.e. with probability $p_{6,1} = g(0)$. Let us determine $p_{86} = P(Z_{n+1} = 6|Z_n = 8)$. Since $8 + Y - m = 6$ implies that $Y = 3$, $p_{86} = g(3)$.

Interestingly, that a transition matrix identical to $\mathbf{P}$ has been introduced in [4], Section 5.9, for car delay in the model of group service, see also (Gertsbakh, 2008; Newell, 1960). Denote by $D = \{\pi_0, \pi_1, \pi_2, \ldots\}$ the stationary distribution for the Markov chain with matrix $\mathbf{P}$. Consider a modified truncated Markov chain which has M states $0, 1, \ldots, M - 1$ by placing a semi-reflecting barrier in the state M. Formally, this means considering an (M)-state chain with the one step transition matrix $\mathbf{P_M} = ||p_{i,j}(M)||$, where $p_{i,j}(M) = p_{i,j}$ for $i = 0, 1, \ldots, M-1,\ j = 0, 1, \ldots, M - 2$ and $p_{i,M-1} = 1 - \sum_{j=0}^{M-2} p_{i,j}$ for $0 = 1, 2, \ldots, M - 1$. In practice, we take $M >> m$, and the probabilities $p_{i,j}$ are very small for $j \ge M$. Physically, the truncated matrix $\mathbf{P_M}$ describes a random walk which behaves for the states $i = 0, 1, 2, \ldots, M - 2$ exactly as the original Markov chain. When it is in state i, it goes to $M - 1$ with probability $p_{i,M-1}$, or jumps "backward" into lower state $k,\ k < i$ with probability $p_{M-1,i}$. This truncated chain describes operation of an intersection with an extra agreement: when the queue reaches (high) level $M - 1$, in the next cycle the intersection will not be entered by the number of cars exceeding m.

Table 2: Queue parameters for Poisson input Y

Parameter	$\rho =$	0.7	0.75	0.8	0.85	0.9	0.925	0.95
Average $Qavr$		0.25	0.45	0.80	1.47	2.98	4.56	7.76
St. dev. σQ		0.90	1.27	1.84	2.80	4.53	6.3	9.5
$\pi_0 = P(Zn = 0)$		0.894	0.833	0.747	0.629	0.472	0.375	0.265

Denote by $D_M = \{\pi_0(M), \pi_1(M), \ldots, \pi_M(M)\}$ the equilibrium distribution for the truncated chain. We state without proof the following

Claim. Denote by Δ the Euclidian distance between D_M and D.
Then Δ tends to zero as M tends to infinity. #

The choice of M for the truncated Markov chain is dictated by the geometry of the link upstream of the intersection, see e.g. Viti (2006). We assume that each PCU occupies 6 meters on the lane along which it moves. Leaving only 1 meter free space between the vehicles in the queue, and assuming that the next upstream intersection is about 500 meters away, we arrive at the value of M=70.

Remark.
It is convenient to calculate the stationary distribution $D(M)$ by raising the matrix $\mathbf{P}(M)$ to power $k = 200 - 400$. By the properties of Markov chains, all rows of the matrix $\mathbf{W}=[P(M)]^k$ represent the equilibrium distribution.#

We conclude this section by numerical results for Poisson input of PCU's (each car = 1 PCU), for various load values ρ. We consider typical intersection with $T_g = T_r = 36$ *sec*, $m = 12$ and $\delta = 36/12 = 3$ *sec* interval to service one car. We have carried out the numerical investigation for the truncated matrix $\mathbf{P}(M)$, assuming $P(Y = k) = e^{-\Lambda} \cdot \Lambda^k / k!,\ k = 0, 1, 2, \ldots$.The load $\rho = \Lambda/(m = 12)$. The results are presented in Table 2 for $\rho = 0.70(0.05)0.90,\ 0.925,\ 0.95$.

4. Numerical Investigation of the Queue for NBD Input Flow

In this section we consider a typical signalized intersection with the red phase of duration $T_r = 36$ *sec* and green phase of $T_g = 36$ *sec*. The maximal number m of cars served during the green phase is assumed to be $m = 12$. The distribution of the number of PCU's per cycle is assumed to be NBD.

We consider several examples of load values $\rho = E[Y]/m \in [0.7, 0.95]$ and degrees of over dispersion $\gamma = Var[Y]/E[Y] \in [1.25, 2.5]$.

The main parameter of our interest is the average queue length Q_{NBD}. The central qualitative result of this paper is the fact that Q_{NBD} considerably exceeds the average queue length Q_{avr} for the Poisson input flow.

It will be extremely convenient to express the parameters of NBD, p and r, via the load ρ and γ. It is easy to obtain the following formulas:

$$p=1/\gamma,\ r=\rho m/(\gamma-1). \tag{11}$$

Since m was assumed constant ($m = 12$), we considered the dependence of the average queue length Q_{NBD} as a function of load ρ for several fixed γ values. If γ is constant, p is constant too, and the only parameter depending on ρ is r. For each fixed pair p, r we considered the corresponding Markov chain with the above described matrix $\mathbf{P}(M)$ and computed the average queue length Q_{NBD} using the stationary distribution $\pi = \{\pi_0, \pi_1, \ldots, \pi_{M-1}\}$:

$$Q_{NBD} = E[Z]. \tag{12}$$

We used in our calculations the following values of ρ: 0.70, 0.80, 0.85, 0.90, 0.925 and 0.95. It turned out that the dependence of the average queue on ρ is very well approximated by a function of type $(a + b\rho)/(1 - c\rho)$. For example, for Poisson input flow

$$Q_{avr} = \frac{-0.7621 + 1.1596 \cdot \rho}{1 - 1.0068 \cdot \rho}. \tag{13}$$

We obtained also approximations for fixed $\gamma = 1.25,\ 1.5,\ 2,\ 2.5$. The corresponding formulas are presented in the Appendix.

Our main results are presented in Fig. 1 in a form of a family of curves showing the queue length dependence on the load, for various γ values.

Fig. 1 leads to the following conclusions.

(1) For a fixed value of γ, the queue length rapidly increases when load approaches to 1.
(2) For the same load ρ, the average queue length for NBD is always considerably larger than the average queue length for Poisson input.
(3) For fixed ρ, the value of Q_{NBD}/Q_{avr} increases with the increase of $\gamma= Var[Y]/E[Y]$.

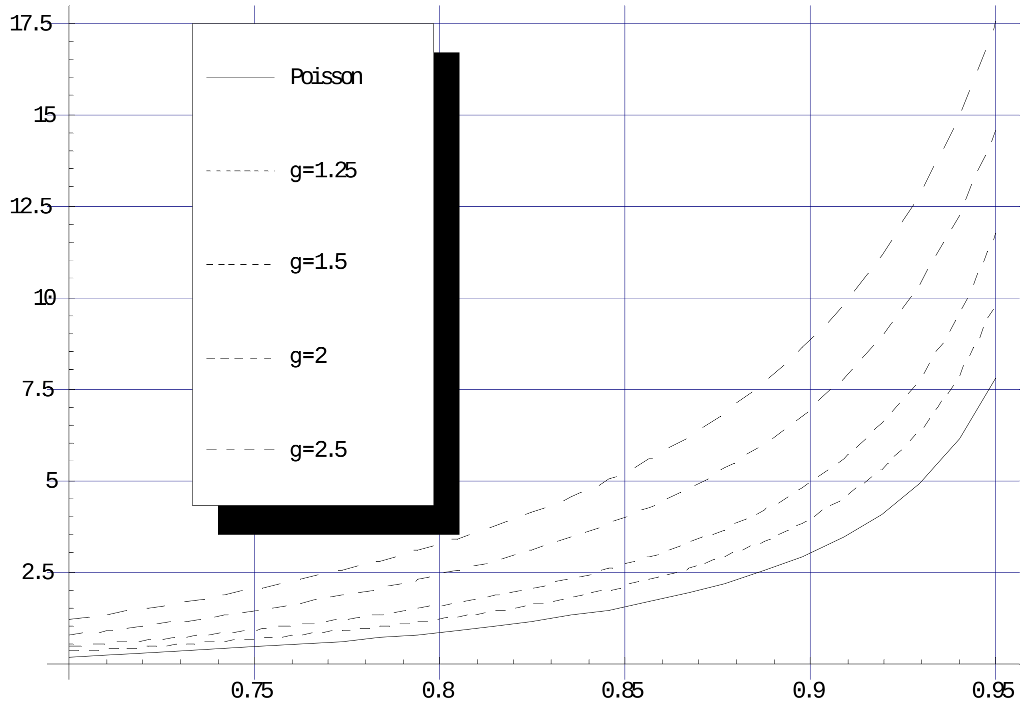

Figure 1. Average queue as function of load

Speaking in terms of vehicles in the input flow, the parameter γ increases with the increase of the percentage of heavy/long vehicles (trucks, buses, trailers etc).

5. Virtual Delay

We define the "virtual delay" as the waiting time of a fictitious "yellow" car arriving at the intersection exactly at the instant when the green light changes to red. This car saw in front of him all Z_n vehicles already waiting in line.

Deriving a formula for average delay and the variance of the delay of a car arriving at a *random* point in time is a rather involved issue and typically is made by assuming a specific model of car arrival process during the green-red phase, see e.g., (Darroch, 1963; Miller, 1963) and the discussion in (Viti, 2006). Contrary to this situation, it is very easy to calculate the mean and variance of the "yellow" delay time. The key is the fact that we know the stationary distribution of the queue $\{Z_n\}$.

If $Z_n = k$, then the yellow car waits $\theta_k = T_r + \delta + Integer[k/m](T_r + T_g) + (k - Integer[k/m] \cdot m) \cdot \delta$, where $\delta = Tg/m$ is the service time of one PCU. Therefore, the mean virtual delay μ_v equals

$$\mu_v = \sum_{k=0}^{M-1} \pi_k \cdot \theta_k \,. \tag{14}$$

Similarly, it is easy to find out the standard deviation σ_v of the virtual delay:

$$\sigma_v = [\sum_{k=0}^{M-1} \pi_k \cdot \theta_k^2 - \mu_v 2)]^{0.5}. \tag{15}$$

The values of μ_v and σ_v are presented in Table 3, for Poisson input and for NBD distribution of PCU's, for various values of parameter $\gamma = Var[Y]/E[Y]$ and various loads ρ.

These results can be summarized as follows. Both μ_v and σ_v increase with the increase of the load ρ. For fixed ρ, they increase significantly with the degree of over dispersion γ.

In our opinion, both virtual mean and standard deviation may serve as conservative ("worst case") characteristics of the delay at signalized intersection. We believe that the mean virtual delay exceeds the actual delay by at least $T_r/2$ (about half of the vehicles arrive at green light and don't wait at all or wait very little) and about half of the vehicles wait time T_r.)

Another advantage of using the virtual delay is that it is easily adjusted to rather a realistic situation of variable input flow, i.e. to the case of non stationary input Y_n. To carry out this adjustment, it is necessary to take into account the varying distribution of Y_{n+1}, $n = s, s + 1, \ldots$, and the present distribution of the queue Z_s. The Markov chain technique is applicable to this case if one takes into account that now the one-step transition matrix $P^{(s)}(M)$ will depend on the cycle numbers s. The analysis of non stationary input flow lies outside the scope of this paper.

Table 3: Mean Virtual Delay and Its Standard Deviation

Input flow	$\rho = 0.7$		$\rho = 0.85$		$\rho = 0.95$	
	μv	σv	μv	σv	μv	σv
Poisson	39.7	2.7	43.9	11.2	74.8	53.0
NBD input, $\gamma = 1.5$	40.5	4.9	48.9	27.3	97.5	76.5
NBD input, $\gamma = 2.0$	42.2	10.1	54.9	31.6	116.3	92.0
NBD input, $\gamma = 2.5$	44.0	14.7	61.4	41.7	130.8	101.9

Appendix

Below are the formulas for the average queue length Q_{NBD} for NBD input flow of PCU's:

For $\gamma = 1.25$, $\quad Q(NBD) = (-0.9106 + 1.4341\rho)/(1 - 1.0043\rho)$, (16)

For $\gamma = 1.5$, $\quad Q(NBD) = (-1.0838 + 1.7487\rho)/(1 - 1.0008\rho)$, (17)

For $\gamma = 2.0$, $\quad Q(NBD) = (-1.6547 + 2.7043\rho)/(1 - 0.0866\rho)$, (18)

For $\gamma = 2.5$, $\quad Q(NBD) = (-1.9851 + 3.3623\rho)/(1 - 0.9800\rho)$. (19)

These formulas estimate the average queue with an absolute error not exceeding 0.05-0.2.
In conclusion, let us note that formulas (16)-(19) are more accurate than rather popular Miller's approximation (1963).

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USERS' PERCEPTION AND REPORTED EFFECTS OF LONG-TERM ACCESS TO IN-VEHICLE TRAFFIC INFORMATION SERVICES MEDIATED THROUGH NOMADIC DEVICES

RESULTS FROM A LARGE-SCALE INTER-EUROPEAN FIELD OPERATIONAL TEST

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ICT-mediated traffic information has been argued to contribute to a more sustainable transport system through affecting drivers. Nevertheless, long-term effects of travellers having access to nomadic in-vehicle systems for traveller information are not well known. This study presents the results from a multi-national large-scale field operational test (FOT). The results show that the users in general were positive to the tested systems and that there were several effects on their driving behaviour but in many cases the effects were limited. Moreover the effects varied between system types. Positive effects were related to comfort, as well as individual and system efficiency. One could also notice that perceived effects were not as high as the participants had expected, leading to some disappointment. Most of the times this was due to the tested systems functioning in a less than optimal way.

Keywords: field operational test, traffic information, nomadic device

1 Introduction

Having access to ICT-mediated systems for traffic information has been argued to contribute to a more sustainable transport system. The European Commission stated already in 2001 that "vehicles throughout the Union need to be equipped with ['technologies that can determine optimum speed at any moment with reference to traffic conditions, road features and external conditions'] as soon as possible, and information systems made accessible to everyone" (CEC, 2001, p. 70). The underlying notion is that people when getting information about the current traffic situation along the intended route, will choose alternative routes and hereby lessen the pressure on the congestion affected roads, choose an alternative mode of transport (such as bicycle or public transport), or even choose not to make the trip.

Even though traffic information systems have been in service for a long time, recent development have brought this type of services, previously only available on variable signs by the road or broadcast through radio, to nomadic devices where the information can be more tailored to the individual. The effects of in-vehicle information services have been previously been studied in simulators and field trials. Studies have however typically focused on safety related systems such as Adaptive Cruise Control and Intelligent Speed Adaptation (Saad et al, 2004). Furthermore, little is known about the long-term effects that in-vehicle traffic information service has on car drivers in real-life traffic, since the few studies on these types of systems have mainly focussed short term effects (Abdel-Aty et al., 1997). In addition, there is a scarcity of studies on mature products as most research has been done on pre-market solutions.

A pre-requisite for this type of systems to have any impact at all is that the users adopt the technology, i.e. that they use it and make use of the information presented to adapt their driving behaviour. One factor that influences users' adoption is perceived benefit why it is important not only to investigate effects as such but also participants' expectations before as well as experiences of using the system. In sum, a better understanding is needed of car drivers' perceptions of in-vehicle information services accessible through nomadic devices, how these perceptions evolve with use and over time, and what effects these systems have on driver and travel behaviour.

2 Method

Five hundred ten drivers from four test sites in three European countries: Finland, Greece, and Sweden, participated in testing mature nomadic in-vehicle systems offering traffic information. The Field Operational Tests (FOTs) were carried out in real traffic in the vehicles of the participants for private as well as work related trips. Participants were recruited through advertising in local media and informed to use the system and service as if they had acquired the system themselves.

Each of the four test sites tested a different traffic information system. The devices differed in physical design as well as in the way the system presented traffic information but all systems informed the participant of disruptions in the transport system, such as e.g. information and warnings about congestion and other temporary disturbances. Two of the test sites, here referred to as Sweden 2 and Greece, tested physical "off the shelf" products while the other two test sites, Sweden 4 and Finland, tested software based solutions that were installed on the participants' smart phones. In the overview (presented in **Table 1**) can be noted that the number of inhabitants differed in the test sites where the systems were distributed, the Greek test site was considerably larger than for example the Finnish test site. (More extensive information on systems and test execution is found in Solar et al., 2011).

Table 1: Short description of systems and distribution sites

Test site	System	Information source	Main distribution point(s)	Approximate no. of inhabitants in test site
Finland	Logica LATIS sw for Symbian phones	Mediamobile Nordic	Oulu / Tampere	190 000/ 351 000
Greece	Sygic Nav sw for Samsung Omnia II (WinMob 6.1)	Traffic Management Center of Athens	Athens	3 700 000
Sweden 4	Trelocity sw for Android phones	Trelocity: Crowd-sourcing/Stockholm Taxi	Online, Sweden	n/a
Sweden 2	Garmin Nüvi 205 WT	Swedish Transport Administration	Gothenburg	950 000

The FOTs lasted over nine months starting in December 2010 with a baseline period of three months. Paper or online questionnaires, distributed to the participants in their native languages, were answered before, during and after the test period. Background data was collected regarding age; gender; car ownership; driving behaviour; driving experience; and traffic information system familiarity. Expectations on the effects of the system that the participants were going to test were collected before actual use but after being introduced to the system.

The study included eighteen effect indicators. Some of these effects can be associated to comfort, i.e. "a satisfying or enjoyable experience" (Merriam-Webster, 2013) and others can be related to efficiency, here defined as the extent to which time or effort is well used for the intended task or purpose. Trust in the information provided by the system, perceived benefit of having access to the system, frequency of use, and opinion of the device tested have been measured in order to interpret the results.

The responses were analyzed using SPSS Statistics 20 for Macintosh. The data was primarily ordinal to its nature and non-parametric tests were therefore used for significance testing (α=0.05). Correlations with magnitudes <0.2 have been deemed small (cf. Cohen, 1969) and thus ignored. There were also a number of open-ended questions in the questionnaires, these have been analysed and grouped using the KJ method (e.g. Scupin, 1997).

3 Results

This section will first introduce some background data. The frequency and type of use are then presented in order to provide an overview to how the respective systems were used. This is followed by an account of reported effects of using the different devices and services offered. Lastly results regarding opinion, trust, and perceived benefit of the tested services are presented.

3.1 Participants

The birth years of the participants spanned from 1933 to 1997. A majority of the participants were male and only 17.3% were female. The most commonly reported distance driven was for all test sites 10 001-20 000 km/year except the test site Sweden 4 where the most common distance/year was longer, 20 000-30 000 km.

More than four out of ten participants had never used a traffic information service before the FOT and a majority of the participants did not have access to traffic information service (i.e. "real-time information about the status of the traffic system, including road works, queues, accidents, etc.") before the beginning of the test period. **Table 2** describes some of the background data collected about the participants from the different test sites.

Table 2: Participant background data

Test site	n	Year of birth (median)	Drivers licence since (median)	Female/ Male (%)	Distance driven/yr (Mm) (median)	Never used traffic info before (%)	Did not have access function before test (%)
Finland	110	1971	1989	15.5/84.5	10-20	42.7	78.2
Greece	88	1974	1995	33.0/67.0	10-20	78.4	89.8
Sweden 4	218	1975	1995	2.3/97.7	20-30	12.9	31.2
Sweden 2	94	1964	1983	39.4/60.6	10-20	72.3	76.6
Total	510	1972	1991	17.3/82.7	10-20	42.5	62.4

3.2 Frequency of use

The frequency of use is likely to influence the effects of having access to a traffic information service, as well as being an indicator of the overall usefulness of the product. The participants therefor reported their use of the traffic information service in relation to the number of car journeys by answering a 5-point Likert scale ranging from "Never" via "Less than 25% of the total number of car journeys"; "Between 25 and 75% of the total number of car journeys"; and "More than 75% of the total number of car journeys" to "Always".

The most common answer to the question "To what extent have you used the traffic information service in relation to your number of car journeys" was "Less than 25% of the total number of car journeys". No statistically significant changes in frequency of use could be found over time, nor were there any differences in use of the system related to gender, age, or frequency of car use.

The use differed however between the different systems tested. *Figure 1* shows for example that the participants at the Greek test site reported to use the system to a larger extent than in other test sites.

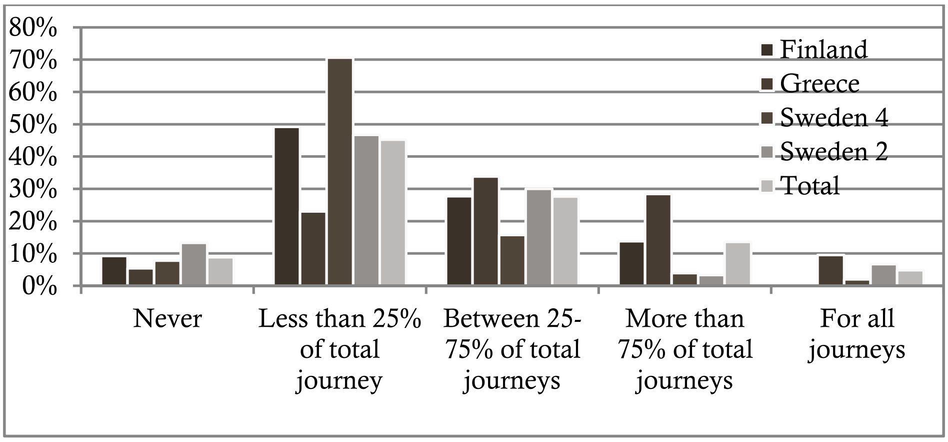

Figure 1. Frequency of use per test site (per cent of valid answers, n_{Fi}=65, n_{Gr}=74, n_{Se4}=51, n_{Se2}=60, n_{tot}=250)

3.3 Use situations

The context in which a traffic information service is used is also likely to influence the effects of having access to that service. The participants were therefore after the test period asked "If you have used the system for some car journeys only are these a particular type of journeys?"

Although more than fourty-four per cent of the participants reported not to have used the service for a particular type of journey, there was some alternatives that stood out. One in four reported having used it when the route/destination has been unfamiliar (see **Table 3**), and a similar percentage reported having used the service when congestion had been expected.

Table 3: Type of journeys when system was used (n=216)

Not for a particular type of journeys	44.4%
When the route/destination has been unfamiliar	25.0%
When congestion has been expected	22.7%
For longer journeys	16.7%
When there has been a time pressure	9.7%
For journeys on highways/motorways	5.1%
For journeys on rural roads	3.2%
When the journey has involved many changes between different modes of transport	2.3%
Other	3.2%

3.4 Reported effects

The participants were after the test period asked to answer the question "Do you think that any of the following have changed due to your access to the Traffic information service?" Fourteen statements were in this way rated on a 5-point Likert scale ranging from "Have radically decreased" via "Have decreased slightly"; "No change"; and "Have increased slightly" to "Have radically increased".

While the overall most dominant answer after the test period was "No change", a number of positive changes were reported. The effects that were found were however predominantly indicated to be slight and not radical changes. If measurements are treated as interval measurements with latent variables efficiency and comfort (cf. Boone and Boone, 2012) the results from the five-point Likert scale show significant changes as presented in **Table 4**.

Table 4: Statistically significant (cut-off level $p_{Wilcoxon}$=0.05, n=240) changes as consequence of long-term access to nomadic in-vehicle solutions for traffic information if measurements are treated as interval measurements with latent variables efficiency and comfort. [1] Indicates effects related to individual travel efficiency, [2] indicates effects related to transport system efficiency, [3] indicates effects related to comfort.

Effect	$p_{Wilcoxon}$	**Direction of change**
Delays when travelling[1,2,3]	<0.0005	Decrease
The time it takes to reach destinations[1,2,3]	<0.0005	Decrease
Fuel consumption[2]	<0.0005	Decrease
Compliance with speed regulations[1,2]	<0.0005	Increase
The distance covered to reach destinations[1,2]		No sign. change
Number of journeys made by car[2]		No sign. change
Use of highways/motorways[2]		No sign. change
Use of rural roads[2]	<0.0005	Increase
Possibilities to choose the optimal route according to preferences (e.g. shortest, quickest)[3]	<0.0005	Increase
Comfort when travelling[3]	<0.0005	Increase
Safety when driving[3]	<0.0005	Increase
Stress associated with travelling[3]	<0.0005	Decrease
Getting stuck in traffic jams[1,2,3]	<0.0005	Decrease
Feeling of uncertainty when travelling[3]	<0.0005	Decrease

The statements to which the largest portion of respondents reported a change were an increase in the "Possibilities to choose the optimal route according to preferences (e.g. shortest quickest)", a decrease in "You getting stuck in traffic jams", and an increase in "Comfort when travelling" (see Figure 2).

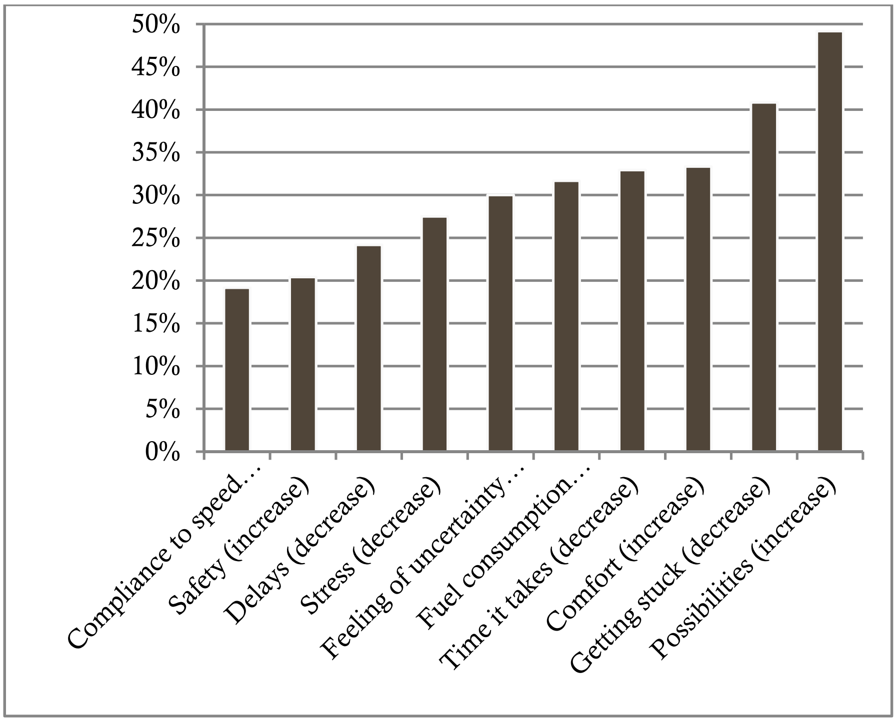

Figure 2. Percentage of respondents reporting a slight or radical change (n=240)

The assessments were however not homogenous. A majority of the statements had responses indicating both "increase" and "decrease". Effects did also vary between the test sites. Participants from the Greek test site reported for example more often a change, for effects deemed central to the service, than did participants from other test sites.

3.5 Expected effects compared to reported effects

The expectations that a user has on a service might influence how or if an effect will be experienced. Disappointment about not experiencing an expected effect might influence use and thus future effects. The responses to the question "Do you think that any of the following will change as a result of your access to the traffic information service?", asked before use but after introduction to the service, was therefore compared to the responses to the question "Do you think that any of the following have changed with your access to the Traffic information service?" asked after the test period for the same fifteen statements (n_{before}=479; n_{during}=298; n_{after}=240). **Table 5** shows the nine of those fifteen statements where the responses had changed significantly ($\alpha_{Wilcoxon}$=0.05, n=233).

Table 5: Statistically significant (cut-off level $p_{Wilcoxon}$=0.05) differences between the expected effects before and stated effects after the test (n=233)

Effect	$p_{Wilcoxon}$	Direction of change
The time it takes to reach destinations	<0.0005	Smaller decrease than expected
Fuel consumption	<0.0005	Smaller decrease than expected
Compliance with speed regulations	0.020	Smaller increase than expected
The distance covered to reach destinations	0.001	Smaller decrease than expected
Use of rural roads	0.037	Smaller increase than expected
Possibilities to choose the optimal route according to preferences (e.g. shortest, quickest)	<0.0005	Smaller increase than expected
Comfort when travelling	<0.0005	Smaller increase than expected
Safety when driving	<0.0005	Smaller increase than expected
Stress associated with travelling	<0.0005	Smaller decrease than expected

The results show that the participants were disappointed with the tested devices and applications not delivering the positive effects that they had anticipated.

3.6 Opinions

The attitude that a user has towards a system for traffic information service is likely to influence the use and effects of having access to that service. The participants were before, during, and after the test period therefore asked to rate their opinion of the traffic information service tested on a five-point Likert scale ranging from “Very negative” to “Very positive”.

The ratings of the traffic information services were (see *Figure 3*) in general positive. In fact 73.1% of the participants rated their reactions as Positive or Very positive after having been introduced to the device, but not started using it. The reaction by the participants turned less positive after the test ($p_{Freidman}$<0.0005, n=211), but was nevertheless mostly positive.

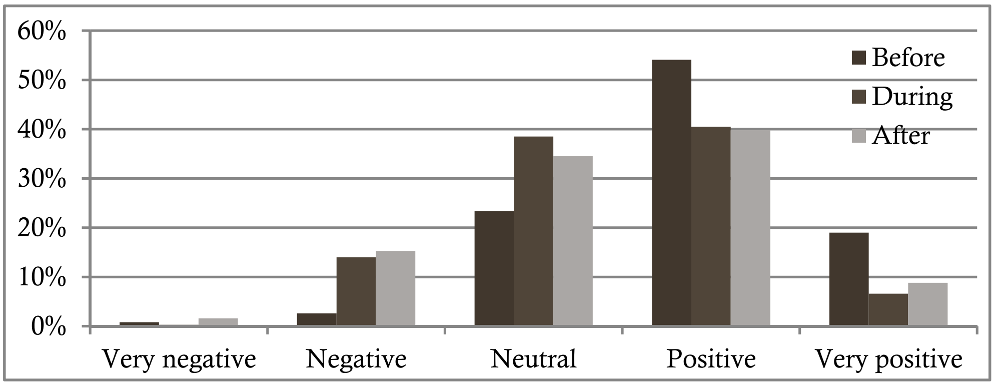

Figure 3. Reaction to the traffic information service (n_{Before}=495; n_{During}=301; n_{After}=249)

The reaction to the system after use did, as seen in *Figure 4*, however vary between the test sites. The systems tested in Greece and Sweden 2 were generally assessed more positively than the systems in Finland and Sweden 4.

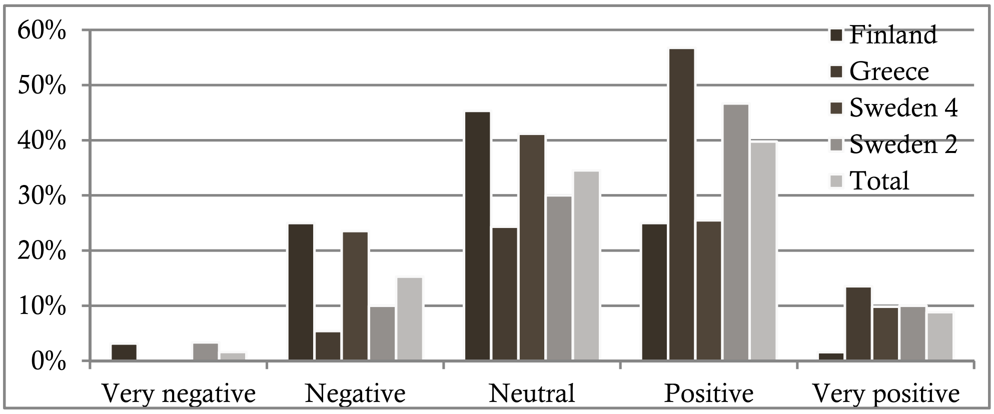

Figure 4. Reaction to the traffic information service after use (n_{Fi}=64; n_{Gr}=74; n_{Se4}=51; n_{Se2}=60; N=249)

3.7 Perceived benefit

Perceived benefit of a traffic information service is likely to affect the use and effect of having access to such a service. The participants were therefore asked before, during and after the test period to rate the benefit of having access to the traffic information service on a five-point Likert scale ranging from “No benefit” to “Very large benefit”.

The participants' expectances for the tested devices/applications included being able to get a good prediction of travelling time and a picture of the traffic situation that enables you to avoid the worst traffic. Traffic information services in nomadic devices could also contribute to less stress, more fluent traffic and, as a consequence, lower emissions.

> *"Since I drive a lot during rush hours and always feel stressed about picking up the kids at kindergarten I hope that this function will help me a lot. I have TMC today and think that the functionality in Sweden is completely worthless…" (Sweden 2 Before trial)*

More than thirty per cent of the respondents assessed the benefit of having access to the traffic information service as Large or Very large benefit (see Figure 5). The results show that to some extent these expectances were met, but certainly not in all cases and to the full extent. The decrease in perceived benefit over time was statistically significant ($p_{Freidman}$<0.0005, n=209).

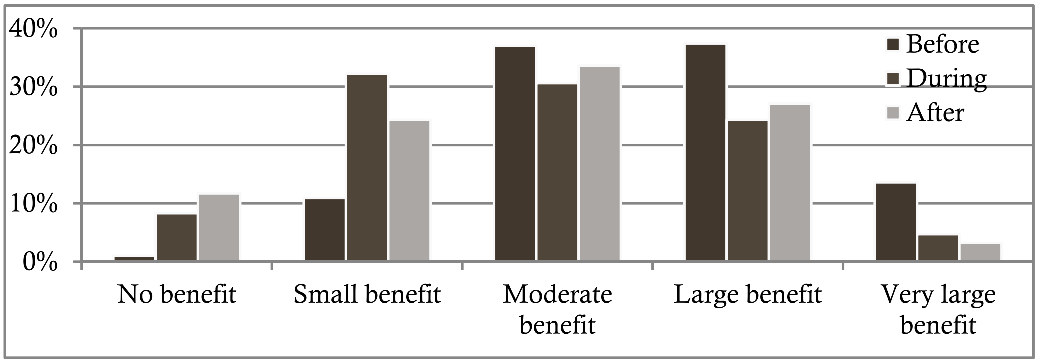

Figure 5. Perceived benefit (n_{Before}=494, n_{During}=301, n_{After}=247)

The perceived benefit varied moreover between the test sites. The participants in Finland reported for example less often than in other test sites the benefit to be Large or Very large. The participants in Greece reported on the other hand more often the benefit as Large (see *Figure 6*).

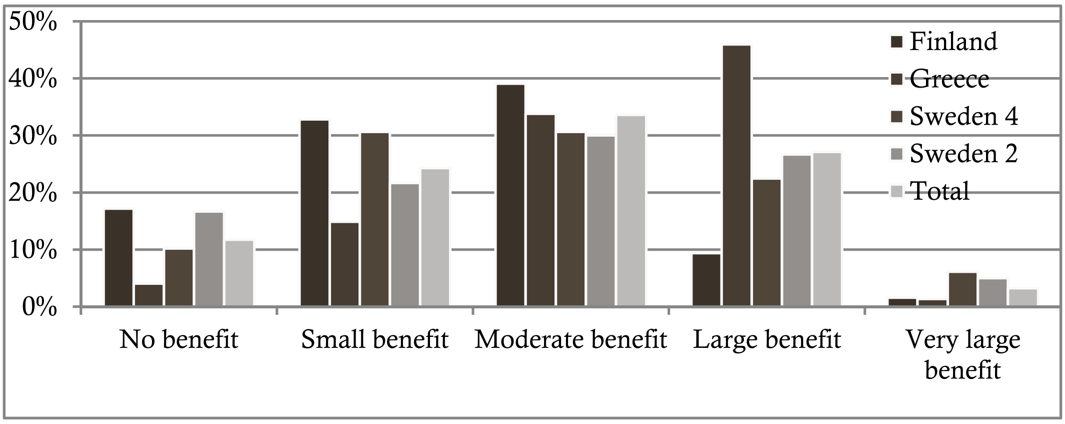

Figure 6. Perceived benefit.(n_{Fi}=64; n_{Gr}=74; n_{Se4}=49; n_{Se2}=60; N=247)

No statistically significant correlation $|\rho|$>0.2 could be found between birth year and ratings of perceived benefit before or after the test period. Neither was any statistically significant difference found between men and women.

3.8 Correlation between reported effects and use, benefits and trust

Table 6 shows that people who found the device to have positive effects, used the system more often, perceived the device as more beneficiary and trusted the system to a higher degree The 18 different effect measures were also tested against gender and age, but no statistically significant correlations were found.

Table 6: Statistically significant Spearman correlations |ρ|>0.2 between reported effects and the reported use, perceived benefits, and trust in the system (n=240)

Reported Effects	Reported use	Perceived benefit	Trust in system
Possibilities to choose optimal route according to preferences according to preferences (e.g. shortest, quickest)	0.494	0.321	0.398
Comfort when travelling	0.443	0.318	0.375
Getting stuck in traffic jams	-0.419	0.294	-0.362
Safety when driving	0.418	-	-
Stress associated with travelling	-0.409	0.314	-0.292
The time it takes to reach destinations	-0.403	0.364	-0.275
Fuel consumption	-0.396	0.348	-
Feeling of uncertainty when travelling	-0.391	0.252	-0.243
Delays when travelling	-0.311	0.301	-0.234
The distance covered to reach destinations	-	0.263	-

3.9 A qualitative analyses of the quantitative results

The free text answers gives us some clues to why the rating of devices/applications as well as the perceived benefits of using such a service went down during the trial. It seems to be related almost exclusively to the quality of the tested devices and services. In this, our findings correspond with that of Lappin (2000) who stated that drivers consult ATIS to reduce the uncertainty of the trip. For it to be successful it must provide value to the driver every day. In order to do so, the service has to be reliable, accurate and easy to use. One can argue that this is even more true for a nomadic device that has to be turned on before every trip to be of use.

A pre-requisite for a traffic information service is that **it actually provides traffic information** for the route that you are taking. The different devices and applications tested received their information from different sources, both traditional (like the national or regional road administrations) and through crowd sourcing.

> *"On many occasions, information on congestion was missing so we ended up in traffic anyway." (Sweden 2 during)*
>
> *"It didn't provide the user with any important information. It concerned only very few streets, that was not part of my journey routes" (Greece post)*
>
> *"Make it work in rural areas" (Sweden 4 post)*

Regardless of the source of the data, it was apparent that traffic information was lacking for the roads that many of the participants travelled, since it mostly covered large roads and/or city centers.

Some participants also experienced information that was not **correct**. There is little doubt that that if you experience the information as incorrect your **trust** in the ICT mediated service goes down.

> *"The info given is of low quality. When red congestion is indicated it has been smooth traffic and vice versa." (Sweden 4 post)*
>
> *"One thing that has come up the latest time is a road work near the home that is not causing any effect on traffic flow. The device anyway informs of a six minutes delay. Cues in rush hour that delays you way more than six minutes never shows up, so the impression on the whole is just so so." (Sweden 2 during)*

Moreover, if you do not **trust** the data, the benefit of having access to the data goes down. The (Spearman) correlation between trust in the information and perceived benefit was strong 0.637 ($p<0.0005$, $n=247$) after the test.

> *"It would have been great if only you could trust the info". (Sweden 4 post)*

The finding that trust is crucial corresponds with Levinson et al. (1999) as well as Abdel-Aty et al. (1997) who independently claimed that people choose the route with highest certainty rather than take a chance with a route that might be faster.

In order to react to traffic information and choose another road, traffic information must be very **quick to update**. A queue can form quickly in rush hours and then disappear just as quickly.

> *"The information about queues or slippery road surface is a bit late, often you are already standing in the queue when you get it. But if it had warned earlier it had been worth gold" (Sweden 2 during)*

Some of the participants pointed out that there exist **alternative sources** for traffic info that are faster, more precise and sometimes already paid for (radio) or virtually free (Waze).

Participants in all of the test sites experienced in some cases that the devices/applications were **not as stable as they expected**.

> *"The Android app works when it wants to. 8/10 it unfortunately doesn't work" (Sweden 4 post trial)*

There were also problems with the **user interface** of the devices, such as icons being too small, screen savers shutting down the screen on mobile devices when no input had been given for some time, and applications lacking a fast and precise way to input destinations.

> *"It did not serve me well. I could not see clearly the traffic sign indicated via small vehicle icons. If was difficult for me to use it" (Greece post)*

> *"There is only one thing that is missing and that is that an address has to be possible to type in. Then the service will be great. As it is now, "click on the map to set your destination", it is completely unusable" (Sweden 4 post)*

A general problem for all the devices and applications tested was that although traffic information was presented, the user did not get any **advice for action**. The participants asked for a system that not only told them that congestion was to expected, but also advised on alternative routes. Already in 1993, Khattak et al. showed the importance of ATIS to provide the user with routing suggestions, but this is still to be implemented in any but the most advanced traffic information systems.

> *"It there was a problem within the scheduled route (e.g. a protest) this should be able to help the driver avoid it. Useful and well communicated information regarding alternative routes would be of value" (Greece post)*

Another fairly common comment was that the traffic information was of little use since the participant did not have **any alternative** routes to choose between, but had to take the same route with or without traffic information.

> *"The routes I usually travel seldom have an alternative, even if there is a queue" (Sweden 2 post)*

This was of cause a bigger concern in smaller cities and rural areas, than in a large city as e.g. Athens were the alternatives are plural. This can be seen in the data as people in Athens ranking the benefits of havin access to Traffic information being much higher than in the other test sites.

4 Conclusion

In general the participants found traffic information available through nomadic devices to be useful, and they also reported the use of the devices and application to have an effect on their driving. They experienced a decrease in getting stuck in traffic and an overall increased comfort when driving. Nevertheless the effects were smaller than the participants had expected. The reasons for this could be divided into three areas: The quality of the data, the options for action (i.e. infrastructure), and the usability of the tested devices and applications.

The four devices and applications tested in these trials were all mature 'off the shelf' products, or very close to market introduction. It is therefore somewhat surprising as well as disappointing that there were so many problems with the products in terms of the quality of the information provided, as well as the usability. These are crucial for the user's experience and evaluation and hence to the market of these products.

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FORMAL AND INFORMAL MACRO-REGIONAL TRANSPORT CLUSTERS AS A PRIMARY STEP IN THE DESIGN AND IMPLEMENTATION OF CLUSTER-BASED STRATEGIES

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The aim of the study is the identification of a formal macro-regional transport and logistics cluster and its development trends on a macro-regional level in 2007-2011 by means of the hierarchical cluster analysis. The central approach of the study is based on two concepts: 1) the concept of formal and informal macro-regions, and 2) the concept of clustering which is based on the similarities shared by the countries of a macro-region and tightly related to the concept of macro-region. The authors seek to answer the question whether the formation of a formal transport cluster could provide the BSR a stable competitive position in the global transportation and logistics market.

Keywords: Baltic Sea Region (BSR), hierarchical cluster analysis (statistics), location quotient, macro-region, transport and logistics

1. Introduction

Regionalisation and globalisation tendencies have brought about the expansion of new forms of active economic integration on the macro-regional level, among these new forms there is also the macro-regional concept for regional development (EC, 2013, 2).

The intensification of international cooperation within the Baltic Sea Region (BSR) started with the launching of the European Union Strategy for the Baltic Sea Region in early 2009. Numerous projects and clusters (StarDust, SmartComp, Transbaltic, etc.) dealing with regional growth helped to achieve a certain level of coordination and complementarity across the countries around the Baltic Sea.

The purpose of this paper is to examine the potential of the BSR for formal cluster development in distribution, maritime and transport and logistics sectors (transport and logistics field) on the macro-regional level. The urgency of the topic is conditioned by the fact that the driven clustering process within macro-regional cooperation shifts the BSR towards becoming a virtual macro-region formation. Macro-regional policy, in its turn, tends to be associated with the identification of macro-regional clusters, which provide a basis for the development of informal forms of cooperation (Herrschel, 2009, 280). Thus, the central approach of the study is based on two concepts.

- The concept of formal (bounded) and informal (virtual) macro-regions.
- The concept of cluster, which is based on the similarities shared by the countries of a macro-region and tightly related to the concept of macro-region.

The authors examine the BSR as a virtual macro-region (which is informal and non-institutionalized), established through the shared cluster policy objectives, and try to answer the main question of the research – can the formation of a formal transport cluster provide the BSR a stable competitive position in the global transport and logistics market? Kabashkin (2014) points out that in order to establish a region as a key component in global logistics networks, it is necessary to envision the strategic positioning of the region within the context of the overall global logistics networks.

The study is based on the cluster approach as an analytical tool of the BSR macro-regional policy for the transport and logistics (T&L) field for the identification of its formal and informal nature. In the authors' opinion, the process of informal clustering prevails in today's macro-regional cooperation. Informal clustering implies realisation of macro-regional projects on the level of collaboration only among business partners. On the one hand, this applied strategic clustering approach contributes to the creation of a competitive business environment, while on the other hand, it may affect the competitiveness (as well as quality) of the macro-regional T&L system as an international supply chain – the supply chain is as strong as its weakest link. The involvement of countries in international projects varies within the region (Finland, Sweden and Baltic Sea Germany are the most active countries in contrast to Norway and Baltic Sea Russia). Thus, one of the problems of cluster approach is concentration on well-performing regions (Dümmler and Thierstein, 2002, 11). Another tendency is the formation of new clusters, which eliminates the use of present regional resources.

As it can be seen, the concept of "cluster" is tightly related to the concept of "macro-region", which is based on the similarities shared by the countries of the region. Below, the authors provide a brief review of literature on clusters and establish some general concepts.

2. Previous studies

In recent years, regional economic integration has been given a fresh impetus in specialised literature and academic publications. Numerous papers are devoted to the outcomes of the "two-dimensional" regional economic policy, namely to (1) regional economic integration at the national level (Boronenko and Zaibote, 2011; Ivanov, 2009; Magomedov, 2011 *et al.*); and (2) regional economic integration at the international (macro-regional) level (Bialasiewicz *et al.*, 2013; Garanti *et al.*, 2014; Hettne and Söderbaum, 2000; Dubois *et al*., 2009 and others). The particularity of the macro-region lies in the character of international cooperation, which can be simplified, for example, through the countries' membership in a certain regional grouping or, *vice versa*, it can be complicated in case of its absence (i.e. the Baltic Sea, the Danube, the Adriatic and Ionian regions). The quality of engagement in the collaboration process may vary significantly as, according to the gravity model of trade, the presence of physical border can significantly limit the international business activity.

Bialasiewicz *et al.* (2013) examine European macro-regional policies as a threshold in between internal territorial cooperation and external cross-border cooperation, which goes beyond the EU external borders and engages its closest neighbourhood. The authors of the paper have adopted some basic principles of regional cooperation and applied these to macro-regional cooperation.

Herrschel (2009) studies the formal and informal nature of regions and highlights that business clusterings are informal because they are largely a personality-based form of cooperation, which may be potentially dangerous. Herrschel names at least three reasons why it may be so: (1) it has an informal character, which (2) as a rule is time-limited, and (3) it tends to be outside the government hierarchy.

On the basis of these approaches, the BSR's active business clustering policy is of informal character. The region relies on the distribution of the network participants within numerous clusters, which are often episodic in character (StarDust, SmartComp, Transbaltic, etc.). The regions based on this type of clustering policy can be considered non-institutionalised or informal; they are brought together through the shared policy objectives.

A formal region (as well as cluster) is based on a state's rigid regulation; it has a fixed structure and territory. In the authors' opinion, a formal T&L macro-cluster is of major importance in the creation of a competitive macro-regional cluster of formal character. Herrschel (2009) has shown that formal and informal regions can produce negotiated, relatively stable and effective relationships.

Macro-regional/international clusters have been successfully established in the maritime sector. Wijnolst *et al.* (2003) discuss the need of creating a continent-wide cluster in the EU maritime sector, assuming that the maritime sector in Europe might benefit from this organisational form. Macro-regional maritime clusters are in many respects forerunners, especially in environmental technologies. These clusters also share common challenges, such as increasing production and labour costs, a combination of which could bring competitive advantage for the whole region in the future (Karvonen, 2012;Laaksonen and Mäkinen, 2012, 101). Contrary to the maritime sector, railway (due to territorial and infrastructural limitations) and especially road transport lack macro-regional clustering experience – the cluster policy in road transport and logistics is mainly implemented at the national level (Taina, 2012; Laaksonen and Mäkinen, 2012; Nežerenko *et al.*, 2015).

As to Russian research experience, Ivanov (2009) has examined macro-regions as a functional area of the international economic integration at the macro- and mega-regional levels of the global economic system, which contributes to the formation of countries into aggregation and/or international clusters, which share common geo-economic and geo-strategic interests as well as resources, which lead to a favourable development of the international trade and business. Logistics cluster holds a special place in the cluster structures. Magomedov (2014) has sought to study the nature of the logistics cluster and compared it with the logistics system. The analysis shows that the signs of the cluster and the logistics system are almost identical. Magomedov has pointed out that the formation of other clusters depends on the logistics cluster development and that in regional clustering (logistic integration of territories), the development of transport infrastructure is determinative.

Analysis of the literature shows that regional economies (implemented at national or international levels) can achieve practical benefits by employing the concept of clusters (Boronenko and Zaibote, 2011; Garanti *et al.*, 2014). The authors suggest that in order to provide a stable competitive position of the BSR in the global T&L market, the formal and informal character of macro-region must coincide.

3. Methodology

The geographical coverage of the study is the BSR, which consists of eight EU countries and two non-EU countries: Denmark, Estonia, Finland, Baltic Sea Germany (BSG), Latvia, Lithuania, Baltic Sea Poland (BSP), Sweden, Norway and Baltic Sea Russia (BSR).

The methodological and practical contribution of the research lies in identifying the development dynamics of the BSR's T&L field towards a formal macro-regional cluster with the help of HCA on the basis of a 'Specialisation' criterion. The authors suggest that identification of formal clusters of countries may increase the efficiency of the policy-making process in T&L and give further macro-regional development a proper direction. The research structure is presented below (Fig. 1).

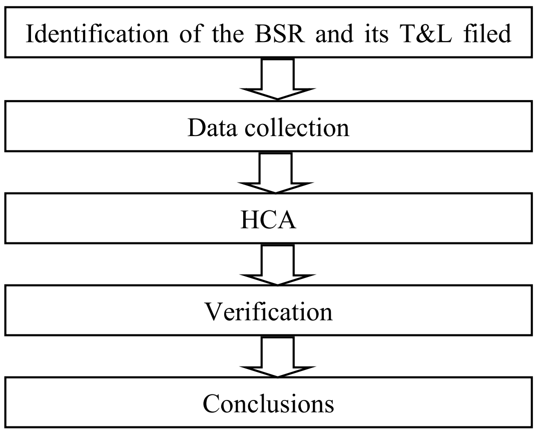

Figure 1. Research structure

Within the paper the authors use the term "clustering" in two meanings: (1) clustering as a way of collaboration in macro-regional projects and (2) clustering as a statistical technique.

Jucevicius and Puidokas (2007), Stejskal (2011), Danjko and Kuzenko (2012), Garanti and Zvirbule-Bērzina (2013) analyse the application of methods for cluster identification. The most widespread method is the input-output analysis, which due to the limited statistical data turns out to be unsuitable for current research. In practice, the measurement of the clusters' performance is a very complicated task because the data necessary for the analysis of the various variables influencing the performance of a cluster are not always available (Prause, 2014).

The methodology used for the analysis of the BSR as a macro-regional cluster is based on quantitative methods (statistical analysis, hierarchical cluster analysis).Statistical data on the cluster indicator "Specialisation" (known as Location Quotient, or LQ) have been collected from Cluster Observatory databases. LQ, can be calculated on the basis of different measures of economic activity. Cluster Observatory uses employment data for identifying regional clusters, comparing the proportion of employment in a cluster category of a region/country to the total employment in the same region/country to the proportion of the total European employment in the given cluster category to the total European employment. Thus LQ says that if a region is more specialised in a specific cluster category than the overall economy across all regions is likely to indicate that the economic effects of the regional cluster have been strong enough to attract related economic activity from other regions to this location, and that spill-overs and linkages will be stronger. (European Cluster Observatory)

There is considerable disagreement in scientific literature about the minimum LQ necessary to identify the specialisation of a region in the particular industry (Garanti and Zvirbule-Bērzina, 2013, 96).

The authors follow the methodology of Cluster Observatory, according to which the measure needs to be at least 2 to conclude that the region/country is specialised in a certain sector.

The analysis covers the BSR's T&L field, which consists of (1) distribution sector (wholesale and retail sale), (2) maritime sector (fishing, aquaculture, manufacture of cordages, tanks, containers, etc.), and (3) T&L sector (land and water transport, shipbuilding, warehousing and storage, etc.). Taking into account that statistical data were not available for some countries, the time frame of the research are the years 2007–2011.

For the identification of formal micro-, meso- and single T&L clusters, hierarchical cluster analysis (HCA) has been applied. The analysis was conducted by means of the SPSS software using Ward's method, which allows forming clusters on the basis of LQ dynamics (Z-scores of the real values were used within the HCA) as a criterion that minimises the total within-cluster variance.

Clustering is a widespread technique of analysis in regional studies, which helps to identify inequalities within macro-regions (Humphries, 2007, Hernández *et al.*, 2009; Mimis, 2013; Nežerenko *et al.*, 2015).The idea of hierarchical clustering lies in the identification of each object initially as a single cluster (or, in this case, country). Then, in multiple iterations, the two nearest clusters are merged into a bigger one – a T&L micro-cluster. Meso-clusters emerge at the second stage of HCA, when two adjacent micro-clusters merge into a bigger one. After a few iterations, the algorithm reaches the final cluster structure – a single T&L cluster. Dissimilarities between countries are shown as dendrograms according to the number of steps in cluster formation.

The overlapping of the formal and the informal natures of the BSR has been determined by using comparative analysis.

4. Findings

The current research is partly based on a previous study by Nežerenko *et al.* (2015), which showed that "formal" clusters can be formed on the basis of handled cargo volumes by the BSR within road, rail and maritime sectors. In the present study, the authors expand the formal cluster formation technique on the indicator LQ used by the European Cluster Observatory (see Appendix) for ranking the regions' potential in the formation of clusters.

The figure below (Fig. 2) presents the average LQ in three sectors for 10 countries of the BSR in the period 2007–2011.

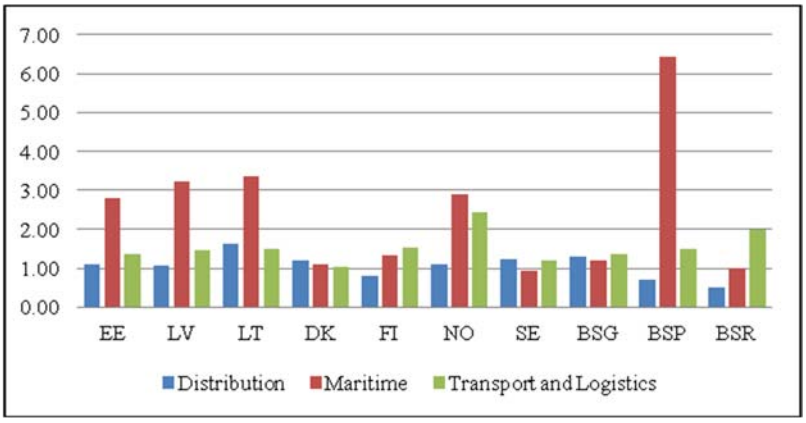

Figure 2. Average LQ in distribution, maritime and T&L sectors for 10 countries of the BSR, 2007–2011

Source: European Cluster Observatory database

From the macro-regional perspective, the BSR demonstrates significant specialisation in maritime sector due to Baltic Sea Poland, Lithuania, Latvia, Norway and Estonia (their average LQ is 2.43). According to the mapping carried out in the course of the MarChain project, the maritime cluster of the BSR comprises the total of 11,900 companies with 211,500 employees (Karvonen and Heikkilä, 2013, 2). The second and the third places belong to T&L and distribution sectors (with LQ of1.54 and 1.07, respectively).

The economic base theory argues that if the LQ for an industry is greater than 1, it is assumed that the region exports the products from that industry. Distribution, maritime and T&L sectors, in that respect, support the international trade of the BSR countries, which, in turn, can activate or, vice versa, restrain the

BSR's transport and economic activity (Nežerenko et al., 2015). Considering that the T&L field demonstrates the highest total number of employees, which is 2 million (Cluster Observatory) within all fields of economy in the region, it can be argued that it forms the economic basis of the BSR.

Further, the authors carry out HCA for mapping the dynamics of micro- and meso-clusters within T&L field sectors.

4.1. Distribution sector

The distribution sector within and among micro-clusters formed at the first stage of HCA by Estonia, Norway and Latvia on the one hand, and Denmark, Sweden and Baltic Sea Germany on the other, demonstrates similarities in the dynamics of their development. These micro-clusters are separated by relatively high LQ and moderate tendencies of its fluctuations during the analysed period (Fig. 3).

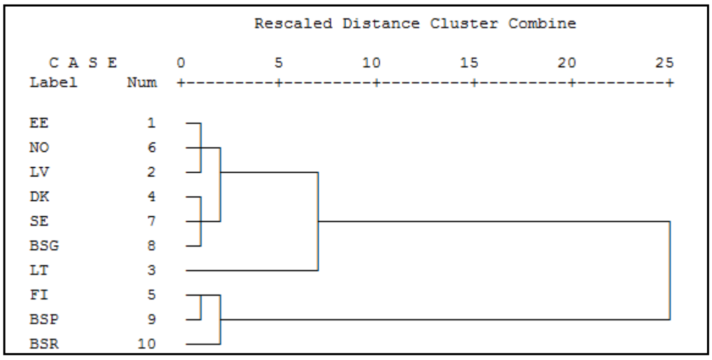

Figure 3. Dendrogram for the average LQ of the BSR distribution sector, 2007–2011(Transform values: Z-scores by case)

Source: The authors' calculations based on the European Cluster Observatory data

Lithuania does not compose any cluster at the earlier stages of the HCA. As shown in Figure 2, Lithuania demonstrates not only the highest LQ, but the highest rate of its positive dynamics in the BSR. The LQ of Finland and Baltic Sea Poland is too low, varying between 0.69 and 0.82. At the first stage, Baltic Sea Russia becomes detached from all other countries with its LQ and also development dynamics, and joins the second weakest micro-cluster of Finland and Baltic Sea Poland at the second stage. In terms of meso-clusters, these countries show the modest potential of the sector development towards cluster specialisation.

4.2. Maritime sector

At the very first stage three clusters were formed (Fig. 4).

- The cluster of Sweden, Baltic Sea Russia, Denmark, Baltic Sea Germany and Finland.
- The cluster of Estonia, Norway, Latvia and Lithuania.
- The micro-cluster of Baltic Sea Poland.

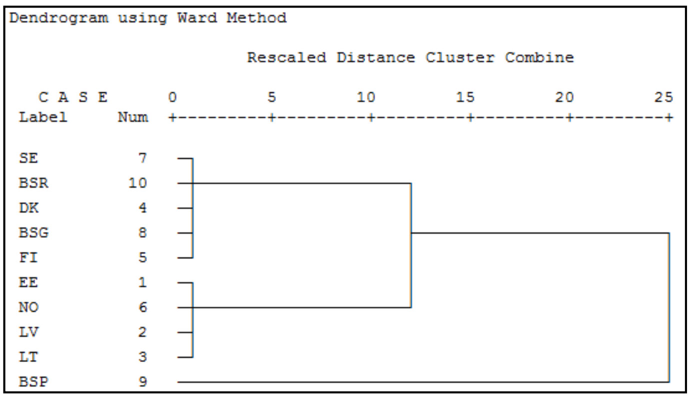

Figure 4. Dendrogram for average LQ of the BSR maritime sector, during 2007–2011 (Transform values: Z-scores by case)

Source: The authors' calculations based on the European Cluster Observatory data

A comparison of all three micro-clusters reveals that they demonstrate significant dissimilarities. Countries of the first micro-cluster have a relatively stable employment level during the periods of the crisis (2008–2009) and the post-crisis (2010–2011). In contrast, the second micro-cluster is more vulnerable, experiencing sharp falls and growth. Among the micro-cluster's countries, Lithuania and Estonia achieved better positions at the end of the analysed period, compared to their performance before the crisis. Despite the fact that Baltic Sea Poland has the highest LQ in the BSR, 6.43 (Fig. 2), it is dissimilar from other micro-clusters in that it is caused by the negative tendency in the employment sector up to 2010 (the loss is about 1 point). Only in 2011 did the positive dynamics lead to a negligible growth in LQ.

4.3. Transport &Logistics sector

In terms of the transport and logistics sector, four micro-clusters have been formed (Fig.5).

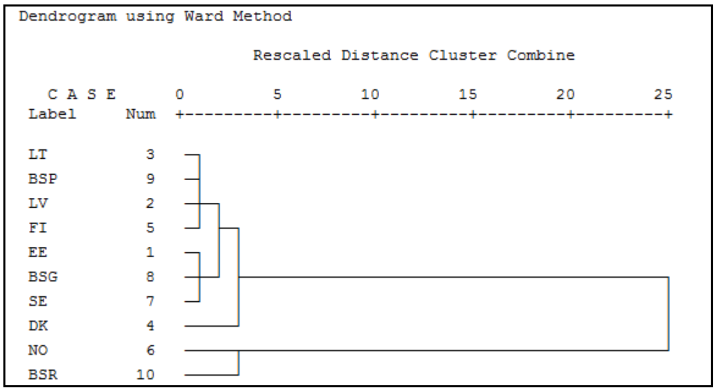

Figure 5. Dendrogram for average LQ of the BSR T&L sector, 2007–2011(Transform values: Z-scores by case)
Source: The authors' calculations based on the European Cluster Observatory data

Countries of the first micro-cluster (Lithuania, Baltic Sea Poland, Latvia and Finland) demonstrate moderate grow of LQ, with the exception of Baltic Sea Poland, whose employment market was hit hard during the crisis. Despite the fact that Estonia, Baltic Sea Germany and Sweden comprise one micro-cluster, some differences in their LQ dynamics can be noticed. Namely, Estonia's LQ was growing during 2007–2011, leaving behind Sweden and Baltic Sea Germany, which could not improve their LQ after achieving the minimum meaning in 2010. Denmark formed a cluster on its own and joined two first-mentioned micro-clusters at the third stage of HCA, demonstrating confident stability. Two non-EU members – Norway and Baltic Sea Russia – form the fourth micro-cluster with a high level of dissimilarity relative to other micro-clusters due to the fact that starting from 2008 the dynamics of LQ was positive, thus the proportion of employment in the cluster category remained at the same level.

4.4. Potential for the development of the Transport &Logistics field

Next, the authors examined the potential for the development of T&L field (Fig.6).

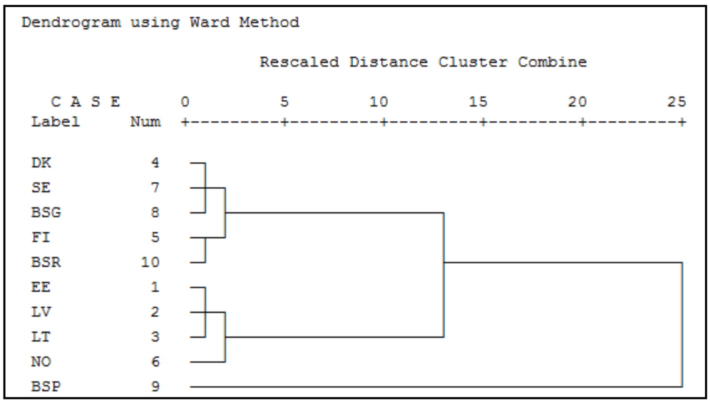

Figure 6. Dynamics for average LQ of the BSR's T&L field, 2007–2011 (Transform values: Z-scores by case)
Source: The authors' calculations based on the European Cluster Observatory data

As a result of the HCA, four micro-clusters emerged featuring the following development dynamics of T&L field.

- Denmark, Sweden and Baltic Sea Germany demonstrate moderate growth rates with average LQ of 1.18 in the analysed period.
- Finland and Baltic Sea Russia were significantly hit by the crisis and demonstrate slow rates of the recovery process. Average LQ in the analysed period was 1.20.
- Estonia, Latvia and Lithuania were not affected by the crisis and demonstrate relatively high rates of growth during the period. Average LQ in the analysed period was 1.95.
- Norway was the strongest micro-cluster with moderate, but stable growth rates. Average LQ in the analysed period was 2.1.

5. Verification of the Baltic Sea Region′s potential toward formation of a formal single Transport & Logistics macro-cluster

National and intergovernmental initiatives are the basis of macro-regional cooperation and can be presented as umbrella projects which cover countries randomly, regardless of the countries' transport sector performances, LQ, and involvement in TEN-T corridors. Next, the authors take a look at the involvement of the BSR countries in eight transport projects, recently launched within the macro-regional T&L policy (Fig. 7).

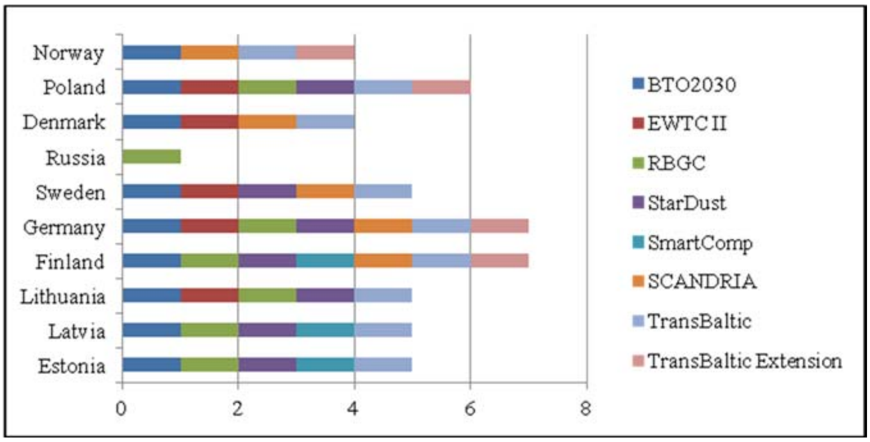

Figure 7. The BSR engagement in "informal" macro-regional cooperation in 2009–2013

Source: Compiled by the authors based on the Baltic Sea Region Programme 2007–2013 database

Baltic Sea Germany and Finland are most actively involved in the macro-regional cooperation. Baltic Sea Poland holds the second place; the third place is shared by Latvia, Lithuania and Sweden. Norway was involved only in two macro-regional projects, Russia only in one project – RBGC launched on the basis of TEN-T development. EWTC II and SCANDRIA are also TEN-T corridors, all together they cover practically the whole macro-region, and these projects tend to be formal. Other projects are informal business clusters initiated mainly in the maritime sector in the case of which the involvement of countries is lower.

The BSR transport field depends on three factors: (1) international trade; (2) production in industry and (3) sufficient investments in road and rail infrastructure (Nežerenko *et al.*, 2015). These three attributes must be the focus of the macro-regional cluster-policy priorities. At the moment the maritime sector driven by Baltic Sea Poland, Lithuania, Latvia, Norway and Estonia has shown significant LQ–2.43.T&L sector driven by Norway, Baltic Sea Russia and Finland has the LQ of 1.54. Road and rail transport, warehousing and storages and other components need an impulse to ensure diversified development towards a single T&L cluster.

6. Conclusions

In this study, the authors have sought to make a theoretical contribution to the literature by continuing Herrschel's (2009) discussion concerning the concepts of formal and informal regions and clusters. The authors consider that the formal BSR is already bounded and demonstrates potential for the development of its T&L field on the basis of its natural/formal comparative advantages, the accumulation and effective use of which is of great importance for providing the sustainable development of the region in the global context.

In the study three components of the BSR T&L field (distribution, maritime and T&L sectors) has been analysed from the perspective of formal macro-regional cluster formation on the bases of specialisation criterion. The results of the study confirm the viability of the assumption that the formal and informal clusters can coincide.

The maritime sector of the BSR has attributes of both formal and informal clusters. The high macro-regional specialisation ratio coupled with intensive macro-regional business-cooperation form a stable competitive position of the BSR in the global maritime sector. In contrast to the maritime sector, the distribution sector tends to be the weakest component of the BSR T&L field. Its development depends mainly on the business projects of a national character, but still it does not provide the required potential for national and macro-cluster formation as well (with the exception of Lithuania). In its turn, the T&L sector goes beyond national borders, covering all transport modes, warehousing and storage. The BSR demonstrates positive dynamics in the formation of macro-regional cluster, but more intensive macro-regional collaboration is required – the clustering experience varies significantly not only between national countries but between modes of transport and national transport systems unified into international transport corridors.

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Appendix

"Specialisation" criterions of the BSR countries in Distribution, Maritime and Transport & Logistics sectors

Country	2007	2008	2009	2010	2011
Distribution					
Estonia	1.17	1.23	1.07	1.07	1.07
Latvia	1.11	1.06	1.06	1.09	1.10
Lithuania	1.47	1.49	1.70	1.73	1.73
Baltic Sea Poland	0.74	0.73	0.69	0.71	0.71
Baltic Sea Germany	1.41	1.30	1.31	1.27	1.29
Denmark	1.20	1.17	1.18	1.18	1.25
Norway	0.75	1.21	1.20	1.22	1.22
Sweden	1.20	1.17	1.20	1.34	1.34
Finland	0.82	0.76	0.78	0.81	0.81
Baltic Sea Russia	0.46	0.50	0.50	0.51	0.51
Maritime					
Estonia	2.62	2.43	2.59	3.15	3.18
Latvia	3.49	3.17	2.98	3.24	3.27
Lithuania	3.18	2.94	3.23	3.68	3.71
Baltic Sea Poland	6.99	6.41	6.38	6.15	6.20
Baltic Sea Germany	1.23	1.25	1.21	1.20	1.18
Denmark	1.36	1.14	1.00	1.01	1.02
Norway	3.15	2.72	2.79	2.90	2.92
Sweden	1.01	0.93	0.89	0.93	0.94
Finland	1.62	1.43	1.21	1.20	1.21
Baltic Sea Russia	1.08	1.03	0.99	1.00	1.01
Transport & Logistics					
Estonia	1.25	1.24	1.37	1.48	1.48
Latvia	1.05	1.46	1.58	1.66	1.66
Lithuania	1.18	1.45	1.68	1.57	1.57
Baltic Sea Poland	1.95	1.92	1.30	1.14	1.14
Baltic Sea Germany	1.23	1.46	1.48	1.38	1.35
Denmark	1.04	1.03	1.03	1.04	1.04
Norway	3.15	2.72	2.79	2.90	2.92
Sweden	1.33	1.16	1.21	1.20	1.20
Finland	1.50	1.56	1.52	1.58	1.58
Baltic Sea Russia	2.16	1.93	1.95	1.97	1.97

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EMPLOYMENT OF IGBT-TRANSISTORS FOR BIPOLAR IMPULSED MICRO-ARC OXIDATION

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The paper is devoted to the use of insulated gate bipolar transistors (IGBT) for the micro-arc oxidation (MAO) process. The technical requirements to the current switches of power supplies for the pulsed bipolar MAO technology have been developed. The research installation for investigating the IGBT commutation processes during the pulse anode-cathode oxidation has been constructed. The experiments have been performed with its help in order to estimate the possibility of using half-bridge IGBT-modules with different drivers. The research results of the commutation processes investigation for different IGBT half- bridge modules are presented.

Keywords: micro-arc oxidation, insulated gate bipolar transistors, high voltage, commutation process, ballast resistance

1. Introduction

The structural components of different transport devices and systems operate under the conditions of stress – corrosion fracture under the impact of various aggressive factors. For example, the cylinder-piston group of aircraft and automobile engines, turbine blades and nozzle propellers are subjected to high temperature gas erosion. The operating conditions and the increasing performance requirements for technical devices put forward the especially high demand for the structural materials. The materials of the structural components should have a high strength, corrosion resistance, low specific gravity and also withstand considerable thermal stress. The micro arc oxidation (MAO) is widely used to obtain the necessary characteristics of the gate metals group (Al, Mg, Ti, Zr, Nb, Ta, etc.), which is an electrochemical process of oxidation of the surface of metals and their alloys in electrolytic plasma for the purpose of obtaining oxide coatings (Suminov et al.2011).

The structure and composition of MAO coatings depend on the base material, the composition of the electrolyte and the conditions of their formation. The mode of operation, technical parameters and circuit design of the sources of technological current and devices for controlling these sources are important factors. There are many implementations of MAO plants and devices of technological current sources, which are used for performing research and practical tasks of MAO.

Nevertheless, the current regulators used for MAO have low functional opportunities; this fact in its turn restricts the set of properties of the formed MAO coatings. Low functionality of the used current regulators is conditioned by the use of outdated component base (capacitor, thyristor, thyristor-capacitor current regulators) (Suminov et al.2005).

The IGBT transistors (Insulated Gate Bipolar Transistor) have currently become the key components in power electronic devices. The IGBT – transistors provide switching currents up to several kilo-amperes at the reverse voltages of several kilovolts (Martynenko et al.2004). The technology of micro-arc oxidation assumes switching of currents greater than 100A at voltages close to 1000V. The improved functionality of technological current sources (current regulators) for MAO is possible on the basis of modern electronic components of power electronics of IGBT transistors.

2. Requirements for the Technological Current Sources (Current Regulators) of MAO

The electric mode of generating MAO-coatings determines their physical properties at high degree: hardness, porosity, roughness and wear resistance, etc. Using the impulse mode of MAO allows improving the physical characteristics of MAO coatings. The most effective electric modes of the MAO process are achieved with the use of the high-current impulse anode-cathode (AC) polarization, including the usage of periodic anode (A) and cathode (C) polarization with no-current pause. The results of these studies indicate the results as follows (Suminov et al.2005):

1) the change of the total current density correlates with the speed of the oxide layer formation;
2) there exists the maximal thicknesses of the obtained micro-arc coating at A and AC modes;

3) the growth rate and maximum thickness of micro-arc coatings increase with the increase of the current ratio $i_к/i_a$;
4) the maximum thickness of the micro-arc coating increases significantly during the transition from the MAO process in AC mode, at $i_к/i_a=1$ to the combined electric mode: AC – AC -...- C - AC;
5) impulse A, C, AC modes of micro-arc coatings are performed at the following technical parameters:
   - the range of impulse repetition frequencies from 0 to 2000 Hz;
   - the maximum values of currents are hundreds of Amperes;
   - the maximum voltage values are hundreds of Volts.

Thus, the functionality of the current controller determines the set of possible electrical modes and, accordingly, the range of properties of the formed coatings. To perform impulse A, C and AC modes of the micro-arc oxidation, the current regulators must ensure the formation of anodic, cathodic and anodic / cathodic pulses with a frequency rate in the range from 0 to 2000 Hz , with current from 0 to 200 A, with a voltage from 0...550 V, and they also should allow controlling the impulse duration and the duration of the no-current pause.

There are two mechanisms of formation of coatings at the procedure of the micro-arc oxidation: mechanism of anodic oxidation and the mechanism of plasma-chemical reactions. Correspondently, the total current consists of the anodizing current and the current of the micro-arc discharges. The magnitude of the current flowing through the oxidised layers is modified; this means that the resistance of the oxidised layers is also changed, i.e. the oxidised layers are characterized by a resistance varying with time.

A circuit segment "anode – oxidised layer - electrolyte – cathode – lead wires" is the load for the switch components of the current regulators of MAO. The equivalent electric circuit of this circuit segment is shown in Fig. 1 (Gordienko et al.2013).

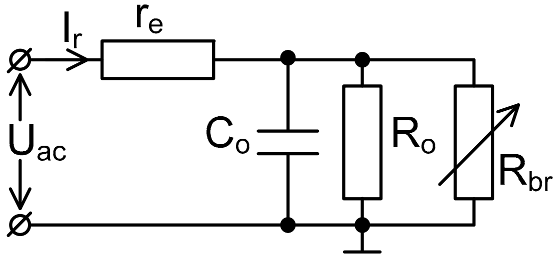


Figure 1. Equivalent electric circuit diagram of the segment "anode – oxidized layer – electrolyte – cathode"

There are the following designations of the components for Fig. 1:
- r_e is the resistance of the electrolyte;
- C_o is the capacitance of the oxide layer;
- R_o is the electric resistance of the oxide layer;
- R_{br} is the nonlinear resistance of the thermal breakdown zone;
- U_{ac} is the voltage of the electrochemical cell (between the anode and the cathode);
- I_r is the output current of the current controller.

The total current of the power supply controller at the MAO consists of the anodizing current flowing through the oxide layer (via R_o and C_o) and current of the micro-arc discharges flowing through R_{br}. The magnitude of the current flowing through the zone of the micro arc discharge changes, since there changes the resistance of the thermal no-current pause zone.

Analysis of the electric modes for the MAO process has allowed formulation of the functional requirements to the current regulator, ensuring the formation of coatings with a wide range of specified properties:
- ensuring unipolar and bipolar asymmetric impulse output currents;
- individual specifying of the levels of anodic and cathodic currents;
- individual specifying of the durations of the voltage impulses action and their repetition frequency;
- restricting the amplitude of the output voltage;
- control of the maximum load current.

3. Experimental Installation for the Study of the Switching Processes of IGBT Transistors

The IGBT - transistors have the advantages of easy control over the MOSFET (minimum energy cost of the control) and low conduction losses, typical for bipolar transistors. Due to these advantages, the properties of IGBT – transistors are close to the properties of the "ideal" electronic key.

Modern IGBT modules are the most powerful and completely controllable semiconductor switches. The IGBT-modules drivers are used to control the IGBT-modules. The IGBT modules drivers are complex complete devices providing the power amplification of the control impulses and the protection of IGBT-transistors and various types of protection of IGBT transistors, including protection against short circuit or over-current.

The experimental installation which a block-diagram shown in Fig.2 has been developed for the study of commutation processes of the IGBT transistors at performing MAO. The experimental installation has been developed taking into account the peculiarities of the process of micro-arc oxidation and the characteristics of the IGBT transistors operation as current regulators.

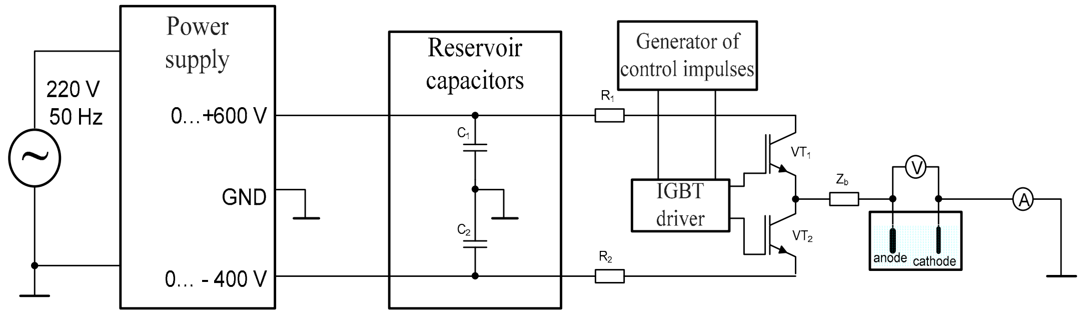


Figure 2. Block- diagram of the experimental installation

The experimental installation includes: power supply, reservoir capacitor unit, current limiting resistors R_o and R_2, the generator of control impulses, the IGBT driver, the IGBT module, the IGBT modules load (“anode - cathode”) and complex ballast resistance Z_b.

The experimental installation uses:

- half-bridge circuit of the current regulator, made on IGBT transistors;
- the IGBT driver controlling the operation of IGBT transistors, to ensure the maximum utilization ratio of the IGBT transistors and protection of the transistors from overload.

Voltage of the power source charges the reservoir capacitors, which are discharged through the circuit "current limiting resistor – the segment “collector-emitter” of the IGBT transistor – the load – instrument shunt”. The control impulses, the power of which is provided by the IGBT driver, are given to the transistors gates for opening the IGBT transistors. The repetition frequency and the duration of the control impulses are set by the impulse generator.

The functional elements of the experimental set have the following technical properties:

1. Power supply: bipolar adjustable voltage source, the range of the positive voltage is 0..+600 V, the range of negative voltages is 0-400 V. The maximum current: the source of positive voltage – 4 A, negative – 6 A. Input voltage primarily 220 V, 50 Hz. Assured isolation voltage from the electric grid is 3 kV.
2. Block of reservoir capacitors: four capacitor of 160 μF. The no-current pause voltage is 1200 V. The Maximum discharge current is 200 A.
3. The impulse generator generates the control impulses: the rectangular impulses with a given duration and the impulse repetition period on three outputs (channels). The duration and the impulse repetition period of the output signals are set equal for simultaneously all channels. However, the impulses of the additional channels are generated with a delay relative to the main channel impulses, and the delay time can be set equal from zero to the length of the pause between impulses. The height of the impulses at the outputs of the generator channels is equal to 5 V. This principle of generating the control impulses on the primary and secondary channels allows performing the impulse AC mode of MAO.

The experimental set allows the connection of measuring devices for monitoring the switching processes and the measurement of parameters and characteristics of the IGBT transistors and IGBT driver.

The IGBT module Infineon IGBT FF 200R17CE4 G1338 has been used for the study of the switching process. The IGBT module FF 200R17CE4 contains the upper and the lower IGBT transistors, forming a half-bridge circuit. The IGBT module FF 200R17CE4 has the following limiting electrical parameters: the maximum voltage collector – emitter is 1700V (at 25^0 C); the maximum collector current is 200A (at 25^0 C), allowing employment of it for executing MAO processes.

The drivers of the IGBT modules of different firms have been used to control the switches of the IGBT modules (Nikitin, 2010): Dual SCALE Driver 2 SD 315 AI, POWERCON MITSUBISHI HYBRID ICs M57962L, SCHI 10/17R, SCYPER 32, 2SD106AI Dual SCALE Driver Core. The results of investigating the listed drivers of power IGBT modules at MAO show that these drivers:

1) have slow response at IGBT transistor turning on and off;
2) do not allow a rapid and flexible change in the circuit parameters of the control and protection of the IGBT transistor;

3) do not secure the protection of the IGBT transistor from reconnection in case of tripping the current protection.

These features of the investigated drivers do not allow using them in the systems used for MAO processes. By the results of the researches, it has been determined that the driver of the IGBT transistors used for MAO shall provide the following functions:

- performance at the edge and the slice of the PWM signal is not more than 100 ns;
- protection of the transistor at current, varying over a wide range of values;
- protection of the transistor from reconnection in case of tripping the current protection;
- galvanic isolation on all controlling circuit;
- high noise immunity.

Considering these requirements, a dual-channel IGBT driver transistor with bipolar controlling impulses has been developed. The main peculiarity of the developed driver is the fact that it provides high performance of the protection circuits of the IGBT transistor by means of circuit designs and selection of electronic components, and there is possibility to set up these circuits flexibly and quickly. The developed dual-channel driver has the following options:

- maximum controlled voltage collector-emitter – 1700V;
- output voltage is +15 V;
- maximum output current is +18 A;
- switching frequency is 100 kHz;
- insulation voltage is 4 kV;
- the slew rate / coefficient of voltage increase is 100 kV/μs;
- the turn-on delay time is 100 ns;
- the turn-off delay time is 100 ns;
- blocking time after emergency (overload) – 1sec.

The integrated ballast resistance is used to reduce the current in the output circuit of the IGBT transistors.

4. Results of the Study of the Switching Process at the IGBT-Transistor Operation on the Oxidized Detail Immersed in the Electrolyte

The oxidation bath, shown in Fig. 3 was made for this research; it was filled with electrolyte. The bath is made of chemically resistant plastic material: vinyl plastic. The dimensions of the bath are 440 mm x 240 mm x 300 mm. The thickness of the walls is 50 mm.

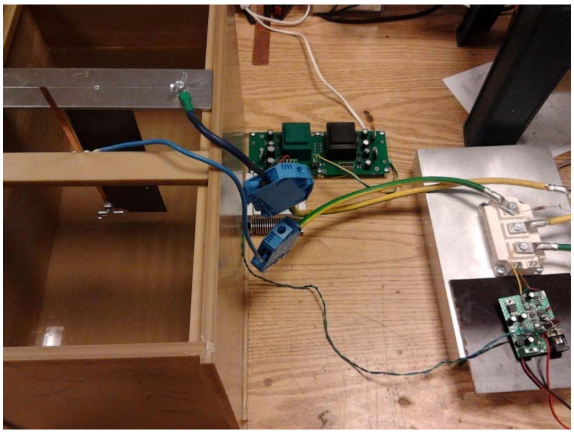


Figure 3. Experimental block of MAO

The micro-arc oxidation of aluminum specimens of size of 20x20mm was performed at the research. The samples were subjected to anodization before performing micro-arc oxidation; anodization was carried out in two stages. At the first stage the anodizing was performed in a solution of CrO3+H3PO4, and at the second phase the plates were placed in a 15% solution of oxalic acid. As a result of anodizing the insulating layer was created on the surface of aluminum plates.

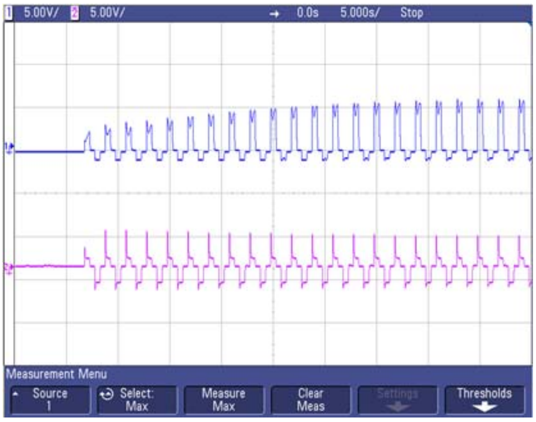
To conduct micro-arc oxidation, the emitter of the IGBT transistor was connected to the anode (aluminum plates), and the cathode was connected to the general wire in accordance with the structural scheme of the experimental block (Fig. 3).

During the experiment the changes of voltage and current on the section of the anode – cathode of the experimental block MAO were investigated (metal of the oxidized plate – oxidized layer of the detail –

electrolyte – stainless steel plate) in impulse AC mode of MAO. The parameters of MAO: height of positive impulse is 400V, the height of the negative impulse is 200V, the impulse duration is 0.5s, the pause length between impulses is 0.5 s, the impulse repetition period is 0.5 Hz.

Since the oxidized layer is characterized by the capacity of $C_{сл}$ (Fig.1), and the resistance of the electrolyte r_0 is insignificant, then the currents can exceed the maximum values at switching. The limit for the currents of the IGBT-transistors is provided by a ballast resistance of $Z_б$. Six variants of inductive-resistive two-poles have been used as ballast resistance in our experiments. Five of them include resistive two-poles with inductor L1 connected with resistor R1 in parallel. The following parameters of inductor and resistor have been used in these connections: variant 1 - L1 = 155 µH, R1 = 13.7 Ohm; variant 2 - L1 = 446 µH, R1 = 6.0 Ohm; variant 3 - L1 = 950 µH, R1 = 0,13 Ohm; variant 4 - L1 = 1,0 mH, R1 = 30.0 Ohm, variant 5 - L1 = 2,5 mH, R1 = 0,35 Ohm. For the sixth variant we used two resistive-inductance sequential two-poles with R1,L1 and R2,L2 which were connected in parallel. The following parameters of sequential circuits were used: L1 = 2,5 mH, R1 = 0.35 Ohm, L2 = 0,53 mH, R2 = 16.2 Ohm.

a



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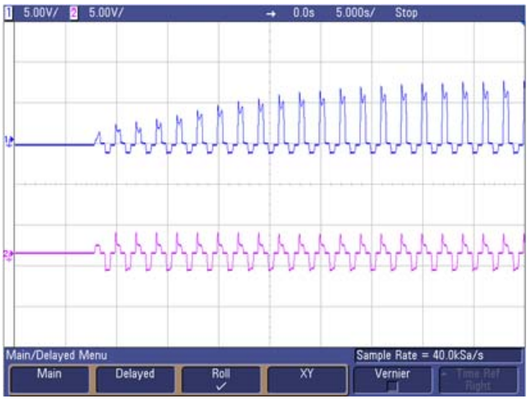

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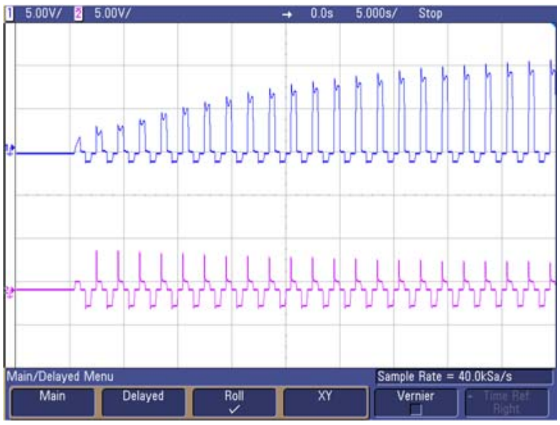

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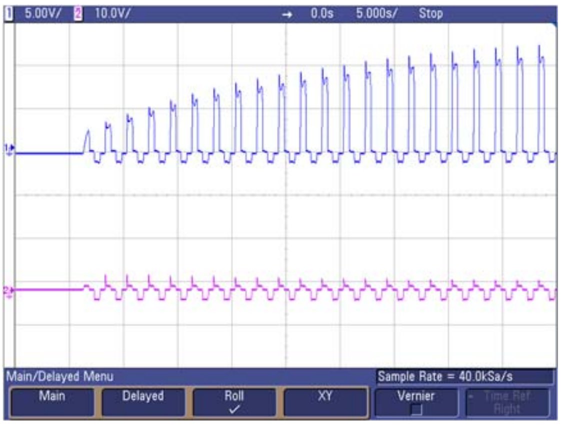


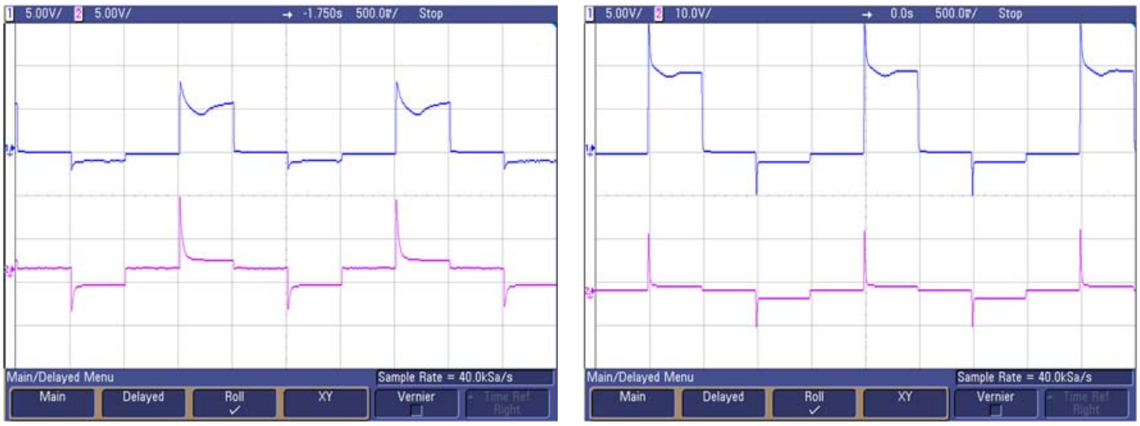
f

Figure 4. Time diagrams of voltages and currents on the section "anode – cathode" of the experimental block MAO at using different variants of ballast resistance: a - variant 1; b - variant 2; c - variant 3; d - variant 4; e - variant 5; f - variant 6

In Fig. 4 the time diagrams of the voltages on the section "anode – cathode"(purple color), and the current at this segment (blue color) are shown. The oscillograms were obtained at using for each of variants the resistive two-pole connection.

Analysis of the current and voltage time diagrams, which are shown in Fig. 4, allows drawing the following conclusions:

1. The duration of the transition process MAO is about 40s. During this time, the resistance of the oxidized layer reaches the value that determines the resistance of all the circuit connected between the emitter and the collector of the upper IGBT-transistor.
2. The transition process within one positive (anodic) impulse is a damped harmonic oscillation. It is explained by the fact that the complete circuit of the load of the upper IGBT transistor is a successive oscillating circuit with losses; it is well illustrated by the time diagrams shown in Fig. 5.
3. The average and peak heights of the anode impulses of voltage and current depend on the ballast resistance.
4. The maximum values of the cathode impulses of voltage do not depend on the ballast resistance, unlike the peak values of the cathode current impulses.



a b

Figure 5. Time diagrams of voltages and current on the section "anode – cathode" of the experimental block after the completion of the transition process of MAO: a - variant 2; b - variant 6

Table 1 gives the values of the properties of the switching processes in impulse AC mode of MAO after the completion of the transition process at using six ballast bi-poles, the parameters of which have been given before.

Table 1. The properties of the switching processes in impulse AC mode of MAO

№	L, μH	R, Om	τ, s	U_0, V	$U_п$, V	I_a, A	I_c, A
1.	155	6,0	30	120	140	17	12.5
2.	446	13,7	35	50	80	17	9.5
3.	950	0,13	35	90	135	27	14.5
4.	1000	30,0	40	65	75	7	4.5
5.	2500	0,35	40	90	150	28	16
6.	2500 530	0,35 16,2	45	110	125	25	14

Table 1 contains the following symbols: τ is the duration of the transition process of MAO; U_0 is the average value of the height of the anode impulses; $U_п$ is the peak value of the height of the anode voltage impulses; I_a is the peak value of the height of the anodic current impulses; I_C, A is the peak height of the cathodes current impulses.

The values presented in the table show that changing only one parameter of the ballast resistance does not allow reducing the peak values of the voltages and currents on the section "anode – cathode" under impulse AC MAO. It is necessary to determine the values of the inductance and resistance of the ballast resistor considering the maximum parameters of IGBT-transistors and the required parameters of the coating.

5. Conclusions

The principal research results are:

- considering the peculiarities of the execution of the micro-arc oxidation and the peculiarities of the IGBT transistors performance as current regulators, the experimental block has been designed;
- the experimental block allows performing the MAO in impulse AC mode and adjust its parameters;
- the necessity of using ballast resistors to protect the IGBT transistors at performing MAO in impulse AC mode is demonstrated;
- the peculiarities of the switching processes at the IGBT-transistor on the oxidized detail, immersed in the electrolyte, are investigated;
- to reduce the peak values of the voltages and the current in the section “anode – cathode”, the inductance of the ballast resistor must be of some hundreds μH and the resistance - of a few Ohms.

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NEW SOLUTIONS BASED ON WIRELESS NETWORKS FOR DYNAMIC TRAFFIC LIGHTS MANAGEMENT: A COMPARISON BETWEEN IEEE 802.15.4 AND BLUETOOTH

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The Wireless Sensor Networks are widely used to detect and exchange information and in recent years they have been increasingly involved in Intelligent Transportation System applications, especially in dynamic management of signalized intersections. In fact, the real-time knowledge of information concerning traffic light junctions represents a valid solution to congestion problems. In this paper, a wireless network architecture, based on IEEE 802.15.4 or Bluetooth, in order to monitor vehicular traffic flows near to traffic lights, is introduced. Moreover, an innovative algorithm is proposed in order to determine dynamically green times and phase sequence of traffic lights, based on measured values of traffic flows. Several simulations compare IEEE 802.15.4 and Bluetooth protocols in order to identify the more suitable communication protocol for ITS applications. Furthermore, in order to confirm the validity of the proposed algorithm for the dynamic management of traffic lights, some case studies have been considered and several simulations have been performed.

Keywords: wireless sensor networks; road monitoring; traffic lights; intelligent transportation systems

1. Introduction

The increasingly growth of vehicles number requires the use of intelligent control systems in order to improve the livability of roads and reduce, as much as possible, accidents. Most of the accidents on the roads occur today because drivers are not aware of upcoming traffic hurdles, like traffic signals, curves and railway lines and so on. Another important issue to be discussed is represented by traffic lights. Accidents, at road intersections, occur for several reasons including the lack of care and the wrong management of traffic lights. The real-time knowledge of road information represents a valid solution to these problems with the main aim to reduce, as much as possible, accidents. The Intelligent Transportation Systems (ITS) aim to improve traffic quality by enhancing safety (Sànchez et al., 2013) through the reduction of travel time (Kothuri et al., 2006) and, as a consequence, of fuel consumption (Rommerskirchen et al., 2013) through gathering, organizing, analyzing, using, and sharing traffic information. Although many researchers focused on these issue, today most of the adopted solutions are very expensive and difficult to install and manage (Fei-Yue Wang, 2010). One of the main aspects on which investigate is represented by the communication medium used to exchange the gathered road information (Skordylis and Trigoni, 2011). Usually, the devices used to gather road data send the information to the central entity, or to a neighbor device, through the use of wired connections. Today, many researchers of different fields, discuss about the possibility to replace, totally or at least partially, the wired networks with the wireless (Eng-Han Ng et al., 2008) ones for these reasons:

- low cost of wireless devices (Gallart et al., 2011);
- ease of installation (Bee-Lie Chai et al., 2010);
- flexibility (Philipp et al., 2012): wireless networks can be used, at the same time, for several purposes and, thanks to the possibility to create several class of services, it is possible to properly manage data traffic flows based on their real time constraints;
- fault tolerance (Pileggi et al., 2010): the failure of one or more network nodes does not affect the functioning of the entire network;
- scalability (Alazzawi et al., 2008): to add or remove a network node is quite simple.

Moreover, wired networks need the power grid to work. As a consequence, it may be really difficult to install these systems in areas hard to reach or where there is no power available. These drawbacks are avoided by the evolution of embedded systems, wireless technologies and Wireless Sensor Networks

(WSNs), characterized by their low size, ease of installation and thanks to their wireless communication they offer scalability with lower costs. Several works in literature discussed the manifold advantages provided by the use of wireless technologies in ITS scenarios (Collotta et al., 2015), such as the reduced costs of installations (Huck et al., 2005), better flexibility, the ability to easily realize temporary deployments (e.g. for monitoring purposes), etc.. ITS applications can be categorized depending on many factors:

- drivers' safety by transmitting accidents and weather information;
- traffic management to minimize congestion or traffic jam and optimize road capacity utilization. This category includes traffic optimization by applying automated traffic assistance decisions and real-time traffic light handling in both isolated and interconnected intersections;
- smart cities. This category includes:
  - navigation orientations before and during a trip in order to minimize cost;
  - pollution prevention;
  - parking locations finding and optimization;
  - road maintenance and repair;
  - public transports management;
  - electronic transactions to allow fees payment on roads and parking;
  - Vehicle To Vehicle communications (V2V).

It is possible to distinguish the main fundamental requirements that should be fulfilled by any ITS technology:

- data reliability: it is of high importance for urban traffic monitoring and management, but this becomes challenging when using WSN due to the low coverage and limited capacity of sensor nodes, added to the "lossy" nature of wireless communication channels. Therefore, ensuring reliable end-to-end communication must be taken into account by any proposed WSN architecture and communication protocols;
- communication security: it must be efficiently handled by appropriate solutions because wireless nature of communications in WSN is more prone to security attacks than wired technologies. The wireless devices may be deployed without physical protection or surveillance and may also store sensitive information relating to users privacy. Therefore, traffic management solutions based on WSN must take into consideration the vulnerable nature of WSN and their components. Specifically, the communication protocols must be secure in order to prevent attacks and sufficiently reliable and fault tolerant to guarantee service continuity in case of failures;
- interoperability and scalability: the rapid development of wireless technologies and different types of sensors imposes on the proposed solutions to take into account hardware heterogeneity to ensure interoperability and scalability;
- real-time communication: many applications need real-time information collection to take in-time decisions. Traffic light monitoring is a typical example, where dynamic crossroad management depends on real-time traffic distribution.

All of these issues can be addressed through innovative ideas that may individually, or in a complementary manner, cover the following aspects:

- design of multi-tiered network architectures: often it is necessary to organize the road areas to be monitored in cells. As a consequence, it is really important to provide mechanisms and protocols in order to ensure the interconnections among cells. Another aspect to consider is represented by the need to ensure the possibility to realize systems aimed to ease the integration of different devices designed to work for specific and different tasks;
- implementation of new mechanisms, or protocols, in order to improve/ensure the reliability of communications on ITS solutions;
- development of techniques to support the transmission of real time constrained data;
- design of decision making approaches based on soft-computing solutions: the management of vehicular traffic flows or traffic lights is a problem often manageable by natural languages. A possible starting point could be represented by new soft computing techniques to improve or re-design aspects of neural networks or fuzzy logic traditionally used by researchers in these fields;

- design and implementation of secure biometric access techniques to ensure the security of personal data that can be stored on the devices.

This work shows a novel network architecture for dynamic management of signalized intersections Specifically, this paper shows an implementation of this approach both on IEEE 802.15.4 (802.15.4, 2006) and on Bluetooth (Bluetooth, 2010) networks in order to determine the best technology meeting the requirements that characterize road monitoring environments. Moreover, in this paper is also proposed an algorithm for the dynamic management of traffic lights. The paper is organized as follows. Section 2 describes main related works in order to determine the current state of art. Section 3 describes the network architecture and the proposed approach showing its implementation both in IEEE 802.15.4 and in Bluetooth networks. Section 4 presents a simulation scenario in order to show network performance obtained by the proposed approach in both network technologies. Finally, Section 5 summarizes the paper reporting conclusions.

2. Related Works

2.1. IEEE 802.15.4 for ITS applications

The management of signalized intersections through the use of IEEE 802.15.4 has been presented in several works in the literature. An intelligent traffic congestion monitoring and measurement system in order to monitor and measure the road traffic congestions is presented by Mandal et al. (2011). The authors propose a rapidly deployable, cost-effective and easily maintainable system that is based on IEEE 802.15.4 protocol and GSM technologies. The proposed approach is based upon calculation of vehicular speed over a stretch of road and the average waiting time of vehicles at road-crossing. After analyzing other technologies both on the market and in the literature, the authors show the obtained results and these are promising.

In another literature work (Zotos et al., 2012) the results of a case study focused on an experimental installation of an intelligent road lighting system are presented. The authors introduces an energy-efficient, intelligent outdoor lighting management and monitoring system where data communication is based on wireless personal area networks. The proposed system maintains lighting at a low level until vehicle or pedestrian motion is detected by a set of proximity sensors. In this case, the level of lighting is increased in order to provide better visibility while the area is occupied and dims to a lower level when the area is clear again. At the same time, data regarding lamp parameters like status and operation dimming level are transferred to the management system via a bidirectional channel that may receive feedback based on a certain system operation profile. Experimental results show that using the proposed system 37% of energy can be saved without causing problems or disturbing daily routing and safety. The combination of communication based on new wireless technologies can be an energy saving and environmentally-friendly solution.

A comprehensive and thorough analysis of implementing a WSN in ITS is presented by Megalingam et al. (2010). Two practical applications of WSN in this context have been identified and implemented by the authors with extensive description of the software and hardware implementation process. In detail, a smart vehicle speed monitoring and traffic routing system is proposed using WSNs in order to monitor and report about the speeding vehicles and also to regulate the traffic. Experimental results reveal that the proposed system is highly flexible and adaptive to traffic conditions. Moreover, the system proposed by the authors is comparatively more economical when compared to the conventional advanced techniques involved in modem ITS due to lower deployment and maintenance costs.

Brahmi et al. (2013) introduce a new adaptive backoff scheme for IEEE 802.15.4 protocol, in order to ensure faster transmission of emergency messages in road environment. The main aim of the authors is to adapt the backoff selection interval to the class of message being transmitted based on a normal distribution. Using the proposed approach, the messages reporting incidents or dangerous events are granted a smaller backoff compared to those carrying periodic traffic flow or weather information. The performance evaluation results, obtained varying both WSN size and periodic messages transmission frequencies, highlight the effectiveness of the proposed approach.

A fuzzy logic controller, for a flexible Quality of Service (QoS) management, is presented by Collotta et al. (2012). The authors show an innovative WSN architecture, based on IEEE 802.15.4 protocol, and a novel algorithm that dynamically enables/disables some video cameras according to the real need to monitor a given area. The algorithm is based on measured traffic volume values through the WSN. The possibility to activate more devices only in case of real need, ensures energy savings. Furthermore, using a fuzzy logic controller, the proposed approach allows to manage easily and in a better way network workload changes.

2.2. Bluetooth for ITS applications

Bluetooth networks are used in several applications for their useful features. The possibility to use real- time information in order to dynamically manage the traffic light cycles is a key aspect of ITS applications. Collotta et al. (2014) propose a Bluetooth network architecture in order to monitor vehicular traffic flows near to a traffic light. The proposed architecture is characterized by a novel algorithm in order to determine green times and phase sequences of traffic lights, based on measured values of traffic flows. However, Bluetooth sensor devices are battery powered, whereby batteries must be replaced after their normal duration (dependent on the use). For this reason the proposed approach is based on real time information provided by a Bluetooth sensor network powered by energy harvesting devices inserted within a road cavity in order to catch the external vibrations, caused by the passage of vehicles. Several simulations have been carried out and obtained results are very promising both in terms of queues management and in terms of the proposed energy harvesting technique.

The travel time of signalized arterial routes using Bluetooth data is analyzed by Tsubota et al. (2011). This data is gathered from scanners, located in signalized arterial routes, when Bluetooth devices pass through the detection range. The analysis carried out by the authors confirms that travel time obtained from Bluetooth records captures traffic characteristics in urban arterial streets, such as morning and evening peaks during weekdays, and bi-modal travel time in a particular link.

Jie et al. (2011) propose a method to measure or estimate the travel time in urban road networks. The authors highlight that urban travel times display a large variation, so that the measurement of a single (average) travel time is not so meaningful. So, the travel time distribution is more relevant than the single value of the average. This distribution can be obtained from observations of travel times of individual vehicles. The distribution of travel time can be measured by Bluetooth scanners that can recognize Bluetooth devices in cars. The authors point out some issues after installing the Bluetooth scanner. In fact, the devices with Bluetooth are often mobile telephones that can be carried by pedestrians, cyclists and passengers of public transport. It is possible that some vehicles have several Bluetooth devices on board. This causes a bias in the estimation of travel time distributions. Furthermore, the exact position where the Bluetooth devices are registered cannot accurately be determined. For longer distance applications like on freeways, such an uncertainty has a smaller impact, while on urban roads the relative impact can be large.

In another literature work (Araghi et al., 2013) an accurate travel time estimation and incident detection using Bluetooth and Wi-Fi technologies is presented. After a through analysis, the authors came to the conclusion that Bluetooth sensors can be considered as a cost-effective method for expanding the monitoring capabilities on a wider road network and providing real time information of the traffic condition both for the traveler’s information systems and traffic management systems. Moreover, the Bluetooth sensor design and configuration of antennae could play a significant role in improving the capability of the proposed system and expanding its application on various traffic monitoring aspects such as incident detection and queue analysis.

The main aim of Bachmann et al. (2014) is to combine a Bluetooth traffic monitoring system with loop detector data for improved freeway traffic speed estimation. Several approach are shown and they are implemented and compared in terms of their ability to fuse data from loop detectors and probe vehicles to accurately estimate freeway traffic speeds. Data from a Bluetooth traffic monitoring system are fused with corresponding loop detector data and compared against GPS collected probe vehicle data. The analysis shows that through data fusion, even a few probe vehicle measurements from a Bluetooth traffic monitoring system can improve the accuracy of traffic speed estimates traditionally obtained from loop detectors.

3. Wireless Network-based solution for traffic light management

3.1. System architecture

The proposed architecture, depicted in Figure 1, is a hierarchical network characterized by two layers: one layer is represented by a wireless sensor network, based on the IEEE 802.15.4 or Bluetooth protocols, while the other one consists of a wired backbone. The IEEE 802.15.4 protocol (802.15.4, 2006), in beacon-enabled mode, makes possible an a priori scheduled communication using Guaranteed Time Slot (GTS). The use of GTS allows to have a communication as deterministic as possible. The WSN architecture here proposed is based on the GTS mechanism.

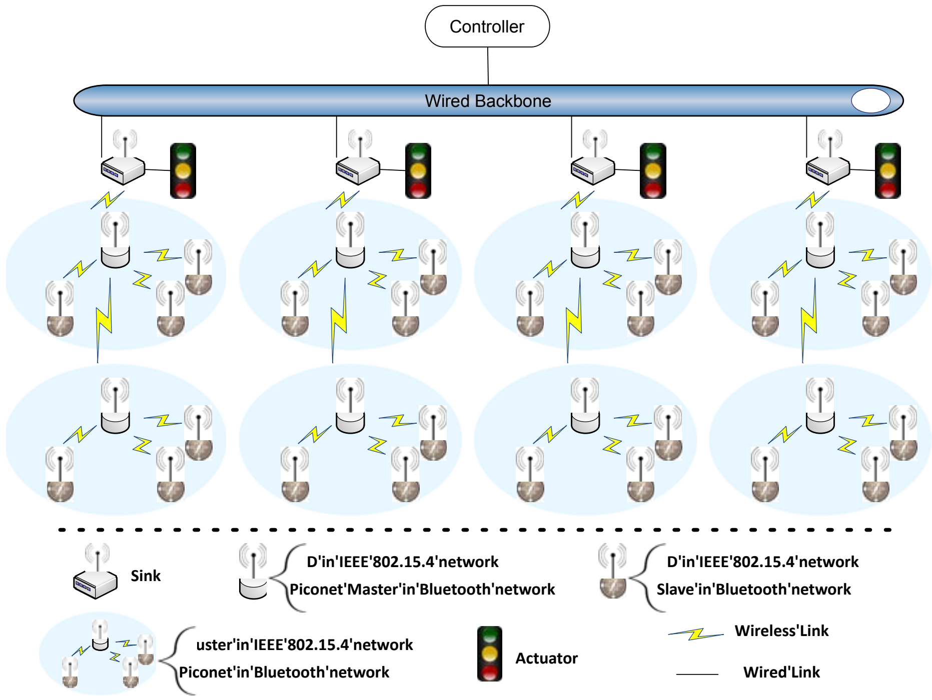

Figure 1. Network architecture

The designed two-tiered architecture is valid for a generic road intersection. Considering the IEEE 802.15.4 protocol, for each intersection several RFD (Reduced Function Device) sensor nodes, organized in clusters and coordinated by special FFD (Full Function Device) nodes, are used. The whole network is coordinated by a sink node that collects and processes all data concerning vehicles. All sink nodes are connected through a wired backbone to a central controller. Each IEEE 802.15.4 cluster consists of a FFD node and several RFD nodes. The FFD node is an 802.15.4 cluster coordinator and it also takes care of routing among clusters. The communication among nodes of the same sub-network is realized using GTS. Periodically, the FFD node sends a data request to its RFD nodes. These nodes reply to the request by sending collected data. Each RFD node is able to detect vehicles in transit, using magnetometers. Thanks to the use of beacons, nodes may enter in sleep mode and save energy during inactivity periods, while waiting for next beacon.

Regarding to Bluetooth (Bluetooth, 2010), it is important to underline that it does not natively support real-time communications. As demonstrated by Collotta et al. (2013), a deadline-aware scheduling should be introduced in order to ensure the satisfaction of real-time constraints (Collotta et al., 2007). Anyhow, the architecture proposed in this paper is based on the standard Bluetooth protocol, without hardware or software changes. In fact, according to Bluetooth standard, a Piconet is formed by a Master node and a maximum of 7 Slaves. If the network requires more than 7 slaves then it is possible to implement a Scatternet, a type of ad-hoc computer network consisting of two or more Piconets. Scatternets can be formed when a member of one Piconet participates as a slave in another Piconet. This Slave transmits data among members of both networks (Collotta et al., 2010). In the Bluetooth approach, the traffic light junctions are monitored using appropriate sensors nodes, (Slaves) and the data gathered by them is then forwarded to their Piconet Master which collect information of the Piconet and forward them to the sink which takes care of data exchanging between Piconets.

As shown in Figure 1, each approach is provided with a sink node, which performs several tasks described below. Specifically, the Scheduling module manages networks real-time traffic, allows bandwidth reservation and avoids collisions using a real-time algorithm, e.g. Earliest Deadline First (Horn, 1974). The Error Handling module controls transmission errors. It works in cooperation with the Scheduling module, communicating the presence of errors, and it adapts the data scheduling to ensure continuous flow of traffic. The Resources Monitoring module manages and shares the availability of resources, e.g. by periodically assessing the channels quality. The Actuator Interface module manages communication with the actuator, by sending commands for the timing of lighting and shutdown of the traffic lights optical units. At periodic intervals, the sink node receives data from sensors and sends them via the wired backbone to the controller.

The controller is characterized by several modules in order to realize the data collection, the data processing and the traffic lights control. The Data Collection module receives and organizes data sent by sink nodes. Data traffic is stored into a database, to allow future referencing for all measurements. The Processing module reads data organized by Data Collection module and processes them trough an appropriate algorithm. This algorithm manages the received data in order to determine the phase sequence and the green time of each phase. Parameters like length of the queue for various lanes and the number of vehicles in transit are used by the algorithm. Finally, the Traffic Lights Control module uses the results produced by the algorithm in order to manage the sequence and the duration of traffic light phases, by sending commands to the sink. These data are then forwarded to the actuator.

3.2. Dynamic traffic light manager algorithm

The dynamic traffic light management allows runtime and real-time regulation of phase sequence and green times duration, based on data gathered by a WSN deployed on the road. The proposed dynamic management algorithm is divided into two steps. In the first step the phase sequence is deter- mined. In fact, the algorithm, based on the queue length for each flow (input variable), assigns a priority to each phase equal to the maximum queue length of that phase. Finally, it determines the phase sequence by sorting them in descending order priority. The second step realizes the green times calculation. The algorithm, for each flow, processes the number of vehicles passed during the previous traffic light cycle and uses this value to determine the current traffic volume (*Q_RT*). This value is used to recalculate the green time duration of the next cycle based on traffic detected. The Figure 2 shows in detail green times calculation flowchart.

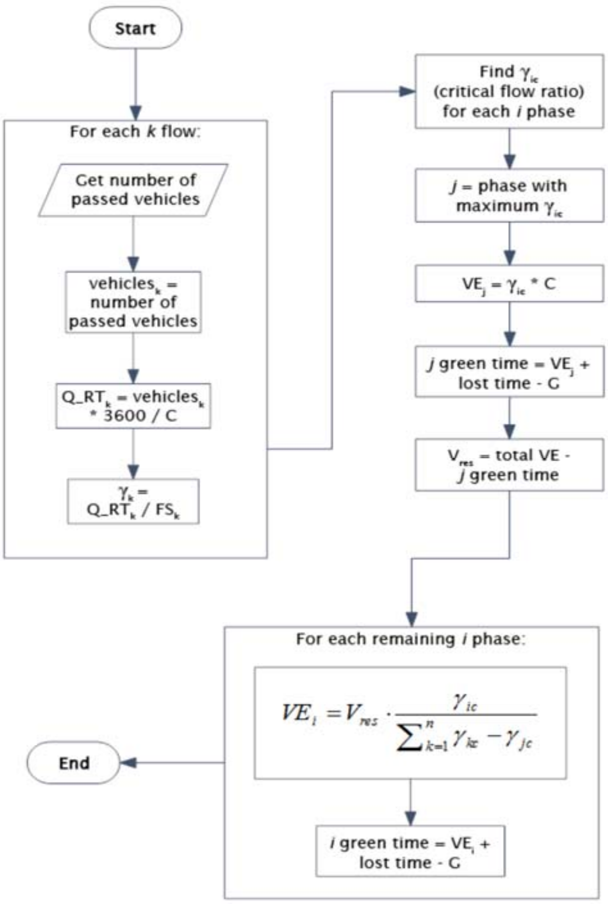

Figure 2. Green times calculation flowchart

The flow ratio γ for a generic flow i is defined as the ratio between the actual or expected incoming stream Q (or volume) and the saturation flow rate FS:

$$\gamma_i = \frac{Q_i}{FS_i} . \quad (1)$$

Data coming from WSN is used to recalculate the incoming stream at every traffic light cycle. For each lane, the number of vehicles passed in each cycle is counted. This data is converted in vehicles/h and subsequently used to recalculate the flow ratio for each traffic flow. For each phase, the critical lane (the one with a higher flow ratio) is established. The phase with the highest flow ratio is found; to this j-phase we assign a saturation flow ratio equal to 1, giving rests to the remaining phases in proportion to their flow ratios:

$$\frac{VE_j}{C} = \gamma_i , \quad (2)$$

where VE_j is the effective green time for the j-phase and C is the traffic light cycle duration. Once VE_j is obtained, it is possible to calculate the j-phases V green time using the following equation:

$$V_j = VE_j + P - G , \quad (3)$$

where P indicates lost time due to start-up and permission times and G indicates the yellow time. The seconds available for remaining phases are calculated as:

$$V_{res} = \sum_{j=1}^{n} VE_j - V_j . \quad (4)$$

For remaining green time (V_{res}) allocation, the following equation can be used:

$$VE_i = V_{res} \frac{\gamma_{ic}}{\sum_{k=1}^{n} \gamma_{kc} - \gamma_{jc}} . \quad (5)$$

Finally, the green time for each i-phase is calculated using the equation (3).

4. Performance Evaluation

In order to validate the benefits introduced by the proposed approach considering both IEEE 802.15.4 and Bluetooth, several simulations have been carried out. Regarding to IEEE 802.15.4, the simulations have been conducted using OMNeT++ (OMNeT++, 2014) considering several cluster topologies consisting of a Full Function Device (FFD) and seven end devices (RFD). The same topology has been used for measurements concerning a Bluetooth network, a Master and seven Slaves forming a Piconet. In this case, simulations have been carried out through the ucbt extension of NS-2 simulator (Network Simulator, 2013). In both cases, the Throughput/Workload (Th/Wl) percentage, the deadline miss ratio, and delays related to both periodic and aperiodic flows have been measured considering packet size of 18 KB and data rate of 180 kbps for each station. It is useful to note that the Throughput is the sum of packets sent by the device and the Workload is the total number of packets that the device has to send. The periodic flows (packets) refer to the monitoring of network resources and to the data collected by sensor nodes. On the contrary, aperiodic flows deal with the error handling and the scheduling.

Figure 3 shows a comparison between results obtained in IEEE 802.15.4 and Bluetooth, respectively. It is possible to see that in the IEEE 802.15.4 network produces better performance. Periodic Th/Wl percentage measured is 81.7% against 67.2% measured in a Bluetooth scenario, while aperiodic Th/Wl percentage obtained is 16.3% against 21.8% obtained in a Bluetooth scenario.

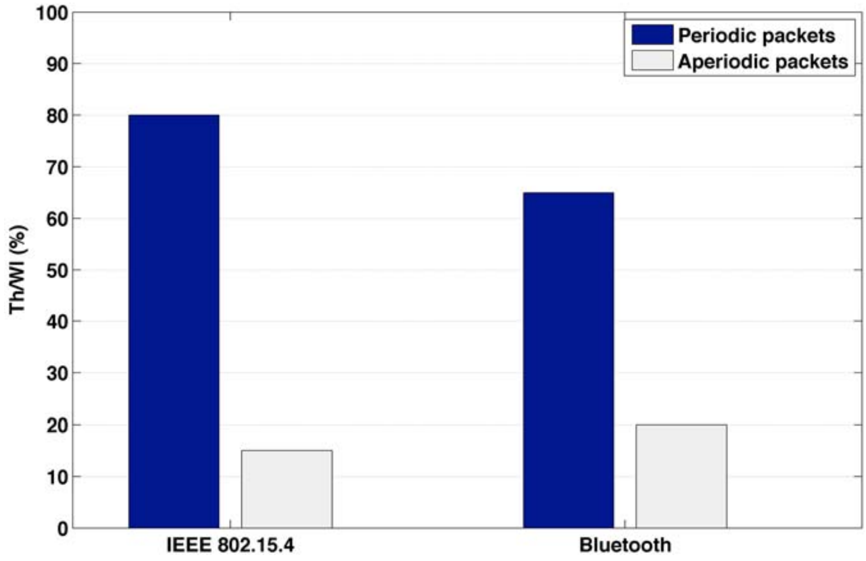

Figure 3. Th/Wl behavior comparison

Deadline miss ratio results in IEEE 802.15.4 and Bluetooth, respectively, are depicted in Figure 4. In an IEEE 802.15.4 network less deadline miss percentage has been measured than Bluetooth for both periodic (4.1% versus 6.4%) and aperiodic traffic flows (1.9% versus 2.1%).

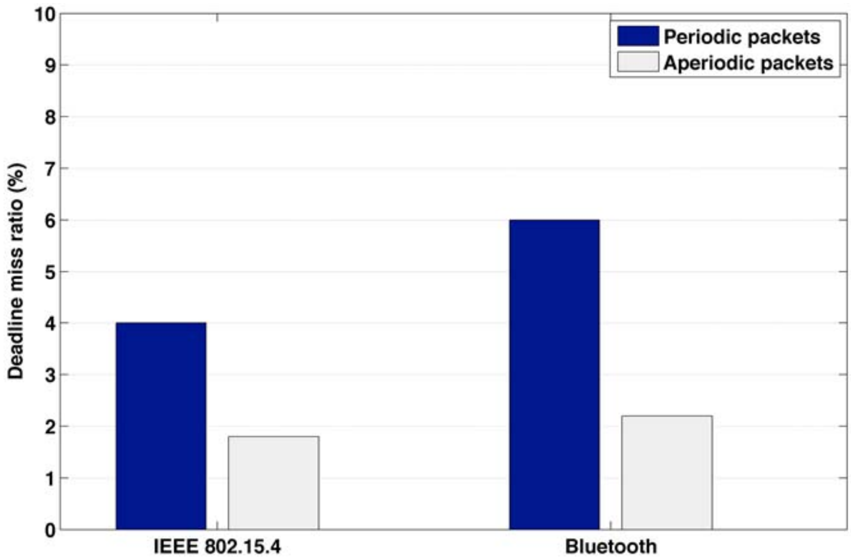

Figure 4. Deadline miss ratio comparison

Finally, Figures 5 and 6 show average delay for periodic and aperiodic packets, respectively. It is possible to see that Bluetooth produces on average a delay of 31.43 ms lower than IEEE 802.15.4 in case of periodic traffic flows while, in case of aperiodic traffic flows, the estimated delay is on average 19.21 ms lower using a Bluetooth network.

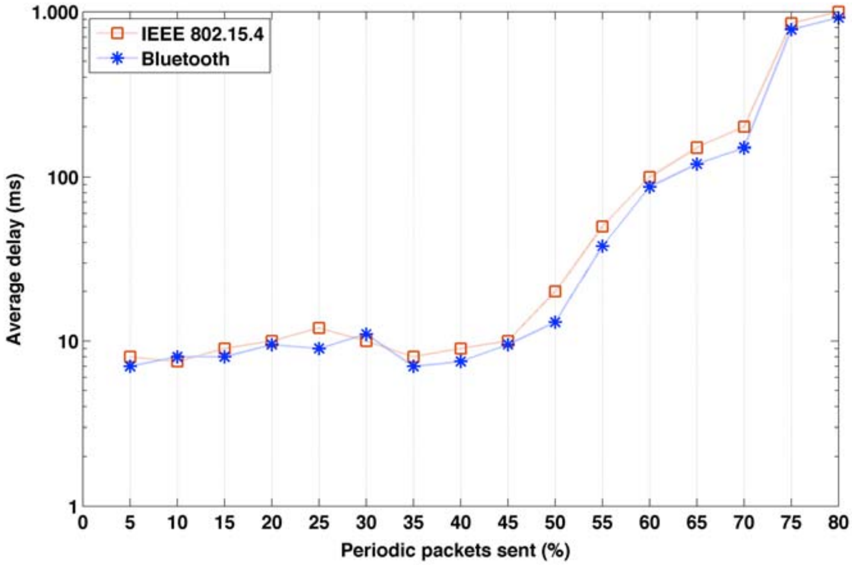

Figure 5. Average delay for periodic packet

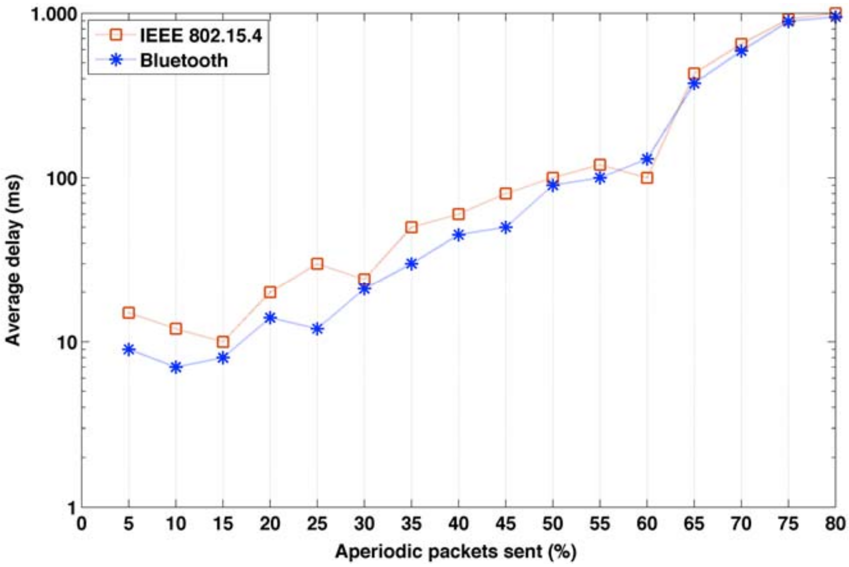

Figure 6. Average delay for aperiodic packet

Furthermore, other simulations have been carried out in order to determine the performance of the algorithm for the dynamic management of the traffic light. The simulations have been carried out both in case of fixed and dynamic traffic light cycle in order to demonstrate the goodness of the proposed approach. Each simulation provides average queue length trend for traffic light cycles. Traffic volume levels set in the different case studies are the following:

- simulation 1 = low traffic volume;
- simulation 2 = medium traffic volume;
- simulation 3 = high traffic volume.

Obtained results, depicted in Figure 7, show a reduction of average queue length in each case study with dynamic management.

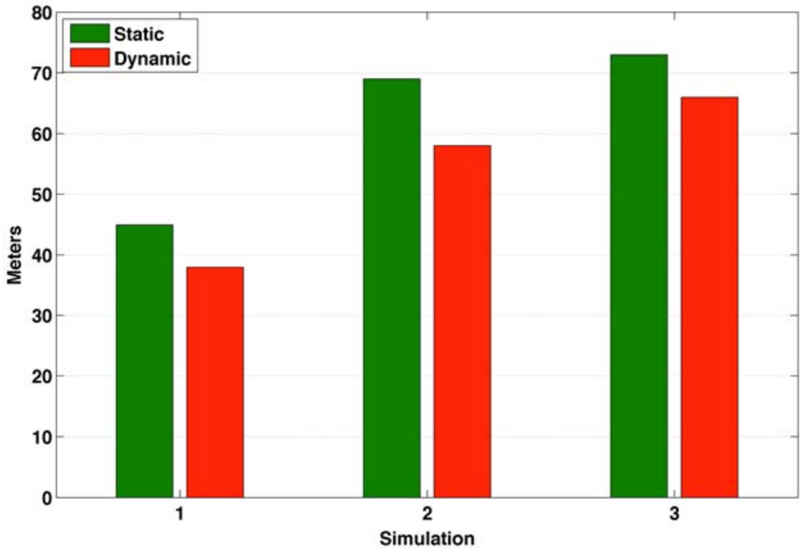

Figure 7. Average queue length: comparison between static and dynamic management

Also, it can be useful to associate the value of average queue length - q_{al} - with the value of junction approaches flow rate - Q_t - and their relationship with the total number of vehicles crossing the intersection in an hour - Q_c (see Table 1). It is helpful to highlight that the Q_c/Q_t ratio between static and dynamic management is quite steady because of the cycle traffic light duration (and therefore the actual green) has been unchanged in both management.

Table 1. Comparison of Q_c/Q_t between Static (S) and Dynamic (D) Management

Simulation	Overall flow rate (Q_t)	q_{al}		Q_c (veh_p)		Q_c/Q_t	
		S	D	S	D	S	D
1	6600	45.14	37.67	6491	6509	0.984	0.986
2	6600	69.82	58.83	6432	6458	0.975	0.979
3	6600	73.14	65.66	6424	6442	0.973	0.976

To understand in detail benefits obtained with traffic light dynamic management, Figure 8 compares peaks of average queue length. It has been observed that for some case studies the difference between static and dynamic management is greater while in other cases it is smaller. It depends on traffic volume entering the intersection from each approach. Because of values considered, it has been found that the algorithm has greater efficiency when the gap between traffic volumes coming from different intersections is higher. The algorithm manages these situations balancing green times according to traffic volume information coming from sensors. There are some improvements even if traffic level is not high, although to a lesser degree. This is due to green times recalculation based on actual traffic conditions. The ability of the designed WSN to fit traffic light phases in order to rebalance the relationship between crossing flows and queued flows, makes the results achieved so far particularly interesting, both in terms of total node efficiency (reduction of the average queue length value) and in terms of penalized / smoother maneuvers selection (transition of queue peaks among different entering maneuvers).

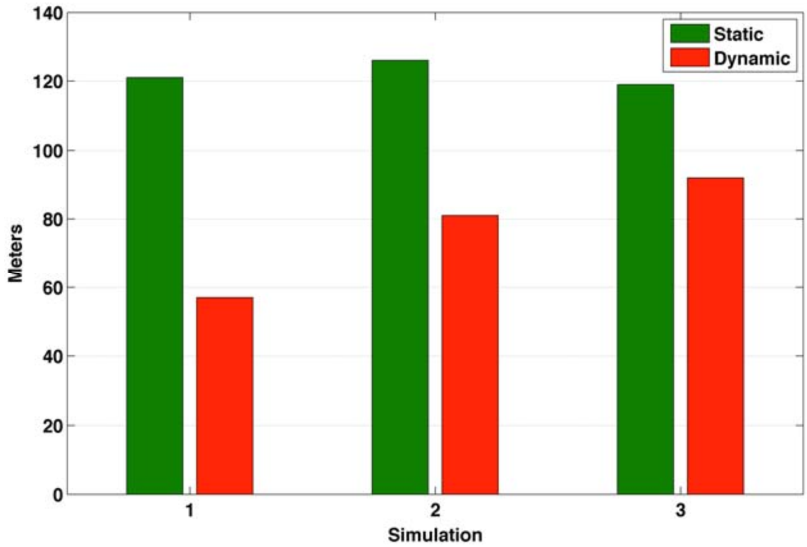

Figure 8. Peaks of average queue length: comparison between static and dynamic management

5. Conclusions

In this paper a Wireless Sensor Network architecture, with multiple levels and based on IEEE 802.15.4 or Bluetooth protocols, for traffic flows monitoring has been proposed. A comparison between IEEE 802.15.4 and Bluetooth solutions has been conducted in order to identify the more suitable communication protocol for ITS applications. The simulation results show that both wireless protocols behave well enough in the Intelligent Transportation System context. In fact, the Th/Wl percentage of periodic flows measured in a IEEE 802.15.4 network is 81.7% against 67.2% measured in a Bluetooth scenario. Similarly, better performance has been obtained in terms of deadline miss ratio for both periodic (4.1% versus 6.4%) and aperiodic (1.9% versus 2.1%) flows. On the contrary, in terms of average delay measured, Bluetooth produces better performance than IEEE 802.15.4. In fact, the measured delay of periodic traffic flows in Bluetooth is 31.43 ms lower than IEEE 802.15.4 while, in case of aperiodic traffic flows, the estimated delay in Bluetooth is on average 19.21 ms lower than IEEE 802.15.4. Considering these results, in applications where the main requirement is to have low packet loss reducing, at the same time, the deadline miss, it is preferable to use IEEE 802.15.4. On the contrary, in applications where it is important to ensure low network communication latencies, it is preferable to use Bluetooth.

Moreover, in this paper an algorithm for the dynamic management of intersections that use data collected by the WSN, to determine the phase sequence and the green times duration, has been implemented. The obtained results illustrate that using the implemented algorithm it is possible to achieve a better management of isolated traffic light junctions.

Regarding future intelligent system improvement, we are working on the improvement of the algorithm and on the optimization of the proposed network architecture. Furthermore, it could be inserted a priority system for emergency vehicles, as well as a preferential system for public transportation vehicles.

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THE VARIANT APPROACH TO THE OPTIMIZATION OF THE POSTAL TRANSPORTATION NETWORK IN THE CONDITIONS OF THE SLOVAK REPUBLIC

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The optimizing process of the postal transportation network can be based on several variables and on different infrastructures. The most commonly used variables for optimization are time and distance. This article is focused on the comparison of the results of the optimization process based on the time and distance variables in the conditions of the Slovak national postal operator.

The different types of the underlying infrastructures (roads or railways) could be used for optimization based on the territory conditions. For the optimization, there has been used the p-median method, that describes the problem of locating P "facilities" relative to a set of "customers" in such a way that the sum of the shortest demand weighted distance between "customers" and "facilities" is minimized.

In the conclusion, the article authors will formulate the rule for selection of the best optimization variables for the postal transportation network optimization.

Keywords: optimization, postal transportation network, distance, time, infrastructure, p-median

1. Introduction

An appropriate location decision is the key to optimally solve a variety of public and private problems, since poor location can result in various negative scenarios. We can consider such decisions as critical, or strategic. In the private sector it can lead to increasing costs, loss of competitive advantage and market share. The location theory provides many different approaches, procedures and solutions to support the decisions of locating facilities, either building new ones or relocating the existing ones. The choice of solution depends exclusively on the nature of the problem, known inputs, decision variables and the outputs we want to achieve. In location models, demands and candidate locations are discretized to simplify the solution. These models also assume that there is an underlying network for the problem, consisting of certain infrastructures, such as transport or other logistic connections. (Droździel, Komsta and Krzywonos, 2008) The distance between demand nodes and facility locations is not necessarily the physical distance. It could be also the travel time, travel costs, etc. (Ahuja, Magnanti, and Orlin, 1993)

The design of a suitable system of postal technology is the most important issue for providing the elementary functions of the postal enterprise. A correct technology decision depends on the chosen postal infrastructure model and specific technological methods and processes. (Droździel, 2008) The designed model takes into consideration the demands of the outside postal environment and the requirements of the high level automation equipment in the conditions of postal enterprises.

1.1. Analysis of the problem

On the basis of the essential postal technology terms, it is important to analyse the main areas which influence the whole technological process of the postal items processing. The analysis determines the critical part of the whole optimization process – the choice of a suitable construction variant of the postal transportation network (Madleňák, 2002).

The most suitable construction variant of the postal transportation network is selected from the experiences of the postal enterprises in two European countries, which are comparable to Slovakia in the geomorphologic character and demographical structure (Čorejová, 1995). The chosen countries are Swiss and Denmark. The construction variant of the transportation network that seems to be the optimum for these countries conditions is a hierarchical three-level model of the postal transportation network (Figure 1).

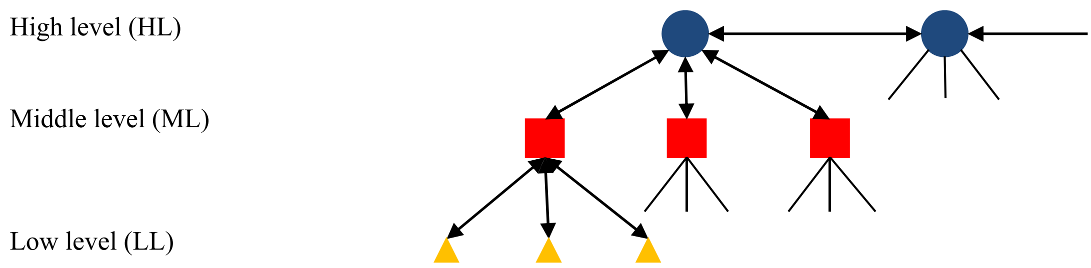

Figure 1. Hierarchical three-level model of postal transportation network (Madleňák, 2003)

After choosing the construction model of the transportation network, it is necessary to determine the number and the placement of each node at all levels of the postal network. For the reasons to reach the real results, the postal optimization process is realized in the conditions of the Slovak postal enterprise – Slovak Post.

The existence of the transportation network of the Slovak Post determined the variant-oriented optimization process. Therefore, a two-phase optimization method has to be created, which, at first, re-evaluates the existence of the middle level nodes and, then, suggests the number and the placement of the highest level nodes of the postal transportation network (Madleňák and Madleňáková, 2006).

2. First phase of optimization

In the first optimization, the phase mathematic-statistics methods could be used to reduce the number of the middle level nodes or to re-evaluate the position of the zone centres. As an optimal for this phase optimization there could be used the methods of multi-criteria analysis (Madleňák and Zeman, 2009):

- rating method;
- method of scaling factors;
- method of standardized variable;

This methods works with the set of demographical and geographical attributes, which represents the characteristics of the particular middle-level regions:

- number of villages (or cities) in the middle-level region;
- number of villages (or cities) with postal offices in the middle-level region;
- number of citizens in the middle-level region;
- total area of the middle-level region;
- total distance between the middle-level region centre and each villages (or cities) in the middle-level region;
- total distance between the middle-level region centre and each village (or city) with a postal office in the middle-level region;

The part-optimized model of the transportation network is depicted in the form of a graph, which served as the basis for the second phase of the optimization (Fig. 2).

The graph G= (V, E) is intuitively defined as a pair consisting of a set of nodes and a set of edges. The graph G is a set of vertex (nodes) V connected by edges (links) E.

The node V is a terminal point or an intersection point of the graph. It is the abstraction of a location such as a city, an administrative division, a road intersection or a transport terminal (stations, terminuses, harbours and airports).

The edge E is a link between two nodes. The link (i, j) is of initial extremity i and of terminal extremity j. The link is the abstraction of a transport infrastructure supporting the movements between the nodes (Drezner, 1995).

For modelling the postal transportation network nodes we used a weighted graph where the weight assigned to each node (a node is location of the postal item processing centre) represent the importance of the node in the graph and the weight assigned to the edge could be represented in two ways:

- metric distance (in km),
- travel time (in minutes).

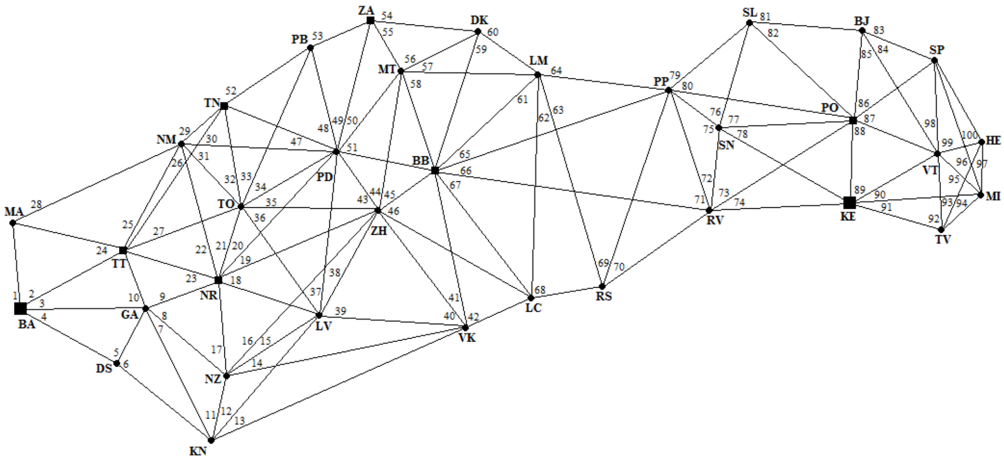

Figure 2. Model of postal transportation network – graph after first phase optimization (Madleňák, 2003)

3. Second phase of optimization

In the second part of the optimization it is important to choose a suitable optimization method to find the optimum number and placement of the highest level nodes of the postal transportation network. One class of location problems deals with covering of demands by at least one facility. We can either find the minimum number of facilities needed to cover all the demand nodes at least once (set covering model) or maximize the number of the covered demands by locating a fixed number of facilities (maximum covering model). Another class is centre problems. Solution to these problems is to find location of a certain number of facilities, so that the maximum coverage distance is as small as possible (p-centre problem). To consider the benefits obtained within the coverage distance or beyond the coverage distance, there is a class of median problems. Since we consider the p-median problem as the most appropriate for our work, we will describe it further (Madleňák, Madleňáková, Pavličko 2014).

3.1. P-median problem

The p-median model locates p facilities to minimize the demand-weighted average distance resulting in minimizing of total costs. The cost of serving demands at a specific node is given by the demand at the node and the distance between the demand node and the nearest facility to that node. This problem may be formulated as follows (Hakimi, 1964):

Inputs

h_j *- demand at node i*

d_{ij} *- distance between demand node i and candidate site j*

P - number of facilities to locate

Decision Variables

$X_j = 1$ *if we locate at candidate site j* $X_j = 0$ *if not*

$Y_{ij} = 1$ *if demands at node i are served by a facility at node j* $Y_{ij} = 0$ *if not*

Minimize

$$\sum_{i=1}^{n} \sum_{j=1}^{n} h_i d_{ij} Y_{ij} \qquad (1)$$

Subject to:

$$\sum_{j=1}^{n} Y_{ij} = 1 \quad \forall i \qquad (2)$$

$$\boldsymbol{\sum_{j=1}^{n} X_j = P} \qquad (3)$$

The objective function (1) minimizes the total demand-weighted distance between each demand node and the nearest facility. Constraint (2) requires each demand node i to be assigned to exactly one facility j. Constraint (3) states where exactly the P facilities are to be located. (Daskin 1995)

While the P-median problem can be solved easily on a tree network, in complex real networks the solution is difficult and time-consuming to find. Thus, a number of heuristic algorithms have been proposed. These heuristics fall into two classes: construction algorithms and improvement algorithms. The basic construction algorithm is a *myopic algorithm* (Figure 3). This algorithm tries to find the initial solution based on the consecutive selection from optimal locations for 1-median problem.

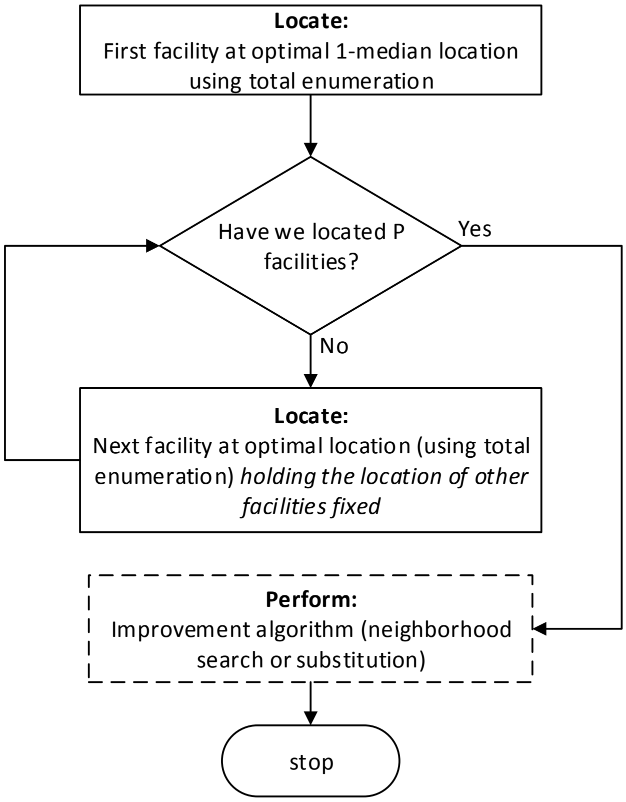

Figure 3. Myopic algorithm with improvement heuristic shown after all facilities are located (Daskin 1995)

Solution is not always optimal for the p-median problems (except 1-median), therefore this algorithm is used only as first step for other algorithms. The aim of the improvement algorithms is to find an optimal or a sub-optimal solution for the facility location. The s*ubstitution algorithm* minimizes the average weighted distance by replacing one of the considered nodes by another node. The improvement of the objective function is observed for each replacement. In case of the improved solution, the nodes are replaced permanently and we continue until all the nodes are considered for a possible location. Anther improvement algorithm is a *neighbourhood search algorithm* (Mesa, Boffey, 1995). This algorithm can also begin with any set of P facilities. For each facility, the algorithm identifies the set of demand nodes that constitute the neighbourhood around the facility. Within each neighbourhood, the optimal 1-median is found by the myopic algorithm. If any sites are changed, the algorithm relocates the demands to the nearest facility and creates new neighbourhoods. If any of the neighbourhoods changes, the algorithm again finds the 1-median within each neighbourhood, and so on. By integrating the myopic algorithm into one of the improvement algorithms, we can find an optimal solution for minimizing the total demand-weighted distance between the demand nodes and the facilities.

4. Results

Variant - time represents the solution for optimizing the location of the main centers in the postal transportation network when we use the travel time between the neighboring nodes as an edge weight. This attribute is specified as the time taken to travel the distance between the nodes of the postal transportation network in minutes. When we process the optimization procedure to allocate the main nodes using the p-median allocation model we come to the following result.

When we want to find only a single main center, the location of this center is placed in the node Žiar and Hronom. The average time needed to serve all nodes from the main node is 139 minutes and the maximum time for covering the farthest node from the main node is 296 minutes.

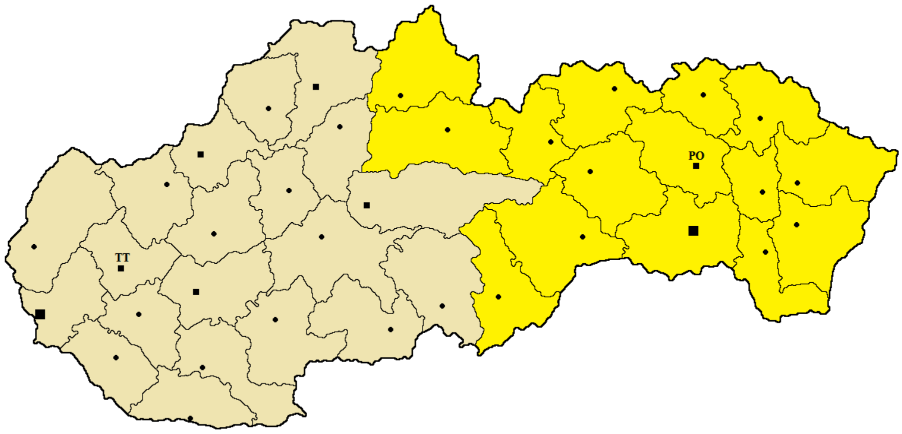

Figure 4. Allocation of two centers in Variant – time model

If we try to find two main centres in the network graph, based on the optimization, these two nodes will be allocated at Trnava and Prešov (Figure 4). Compared with the previous solution we can see the reduction of the average time needed to serve all nodes from the main nodes from 139 minutes to 68 minutes and the maximum time for covering the farthest node from the main nodes to 181 minutes.

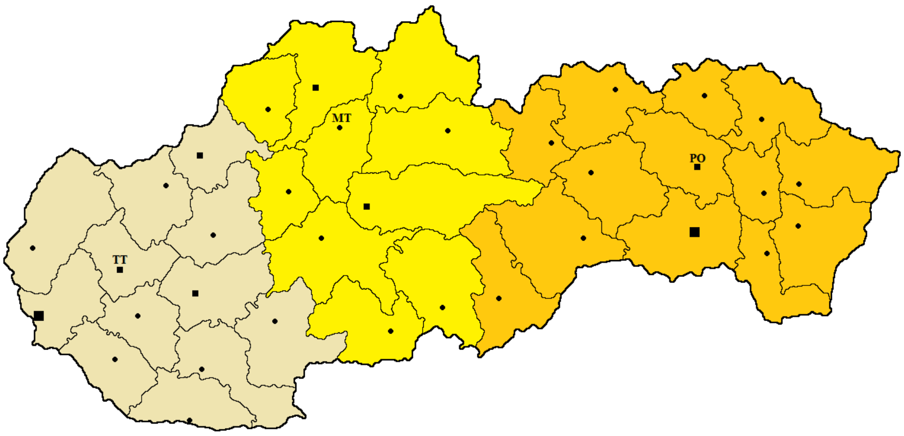

Figure 5. Allocation of three centers in Variant – time model

When we search for three main nodes in the network graph, where the edges are weighted by the travel time, these main nodes will be allocated at the nodes of Trnava, Martin and Prešov (Figure 5). The average time needed to serve all the nodes from the main nodes is reduced to 51 minutes and the farthest node is situated 157 minutes from the head nodes.

When trying to find the four main centres in the travel time criteria edge weighted network graph, the main centres are allocated at the of nodes Bratislava, Nitra, Martin and Prešov (Figure 6). When the postal transportation network will be served from these designated main nodes, the average time needed to serve all the nodes from the main nodes will be 44 minutes and the farthest node will be the same as in the previous variant (3 main centres) 157 minutes away from the main nodes.

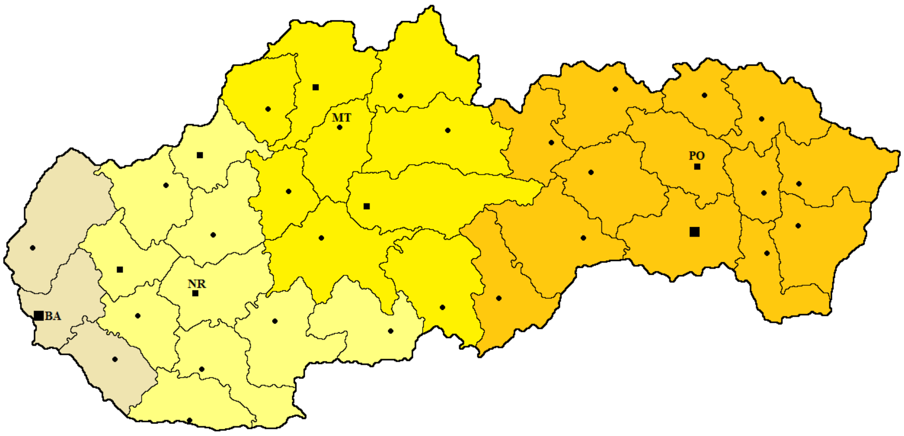

Figure 6. Allocation of four centers in Variant – time model

In the **Variant – distance** we are trying to optimize the location of the main nodes in the postal transportation network based on the assumption that the weighting assigned to the edges of the network graph is specified as the shortest distance between the neighbouring network nodes expressed in kilometres.

If we look for only one main centre in the network graph, then the result of applying the p-median allocation model is the same as in the variant - time. The main node will be located at node Žiar nad Hronom (Figure 7). The average distance between the main node and all nodes of the network was estimated as 151 km. The maximum distance between the main node and the covered nodes network was 314 km.

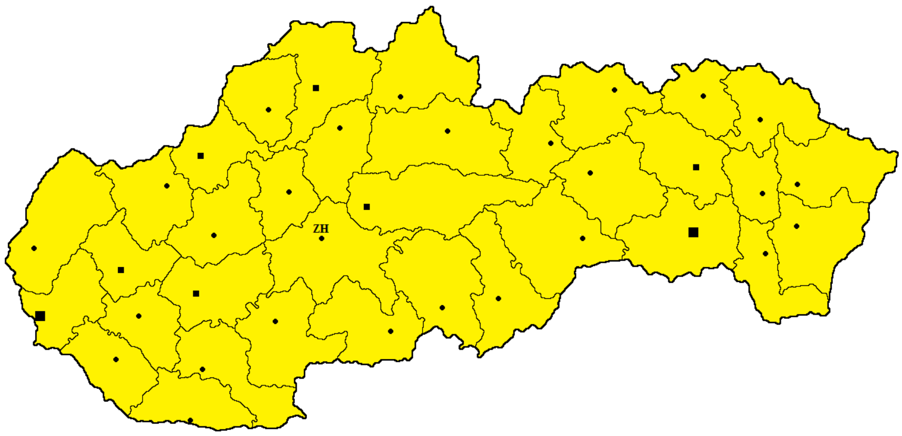

Figure 7. Allocation of one center in Variant – distance model

In the variant when we search for two main nodes in the network graph, the main centres are allocated at Nitra and Prešov (Figure 8). The average distance network of the nodes from the central nodes was 79 km and the maximum distance between the main node and the covered nodes network was 171 km.

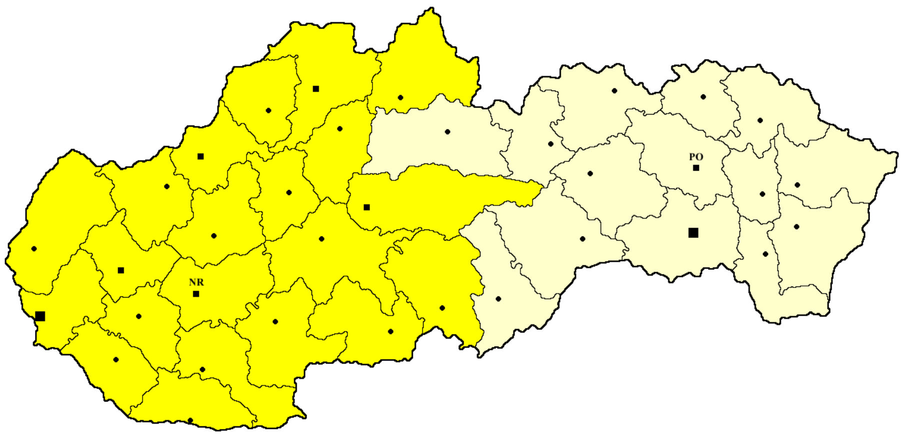

Figure 8. Allocation of two centers in Variant – distance model

The biggest difference between the variants of distance and time is just in the case when we search for three main centres in the postal transportation network. In the variant – time, the main centres were allocated at Bratislava, Prešov and Prievidza (Figure 9). The average distance between the central nodes and the covered network nodes was 53 km and the maximum distance between the main node and covered nodes network was 148 km.

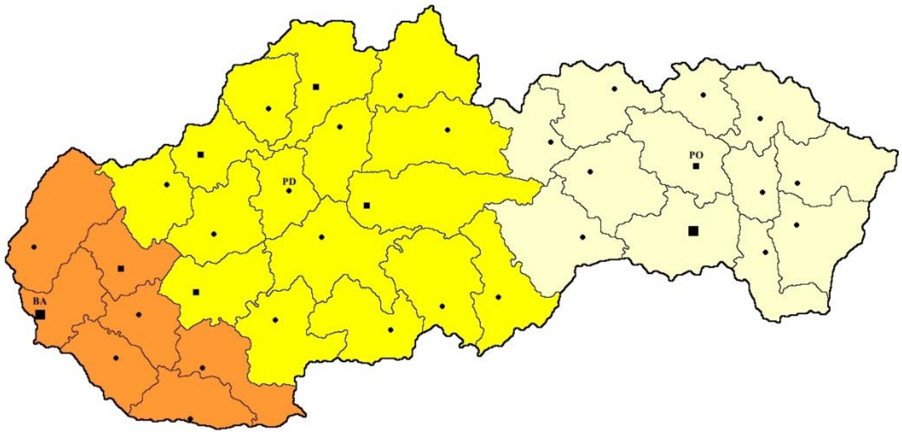

Figure 9. Allocation of three centers in Variant – distance model

The results of four main nodes allocation in the network graph were the same in both variants of distance and time. The main centres were allocated to Bratislava, Nitra, Martin and Prešov (Figure 10). The attribute average distance between the main nodes in the network and the covered nodes was 43 km while the farthest node was 150 km away from the main nodes.

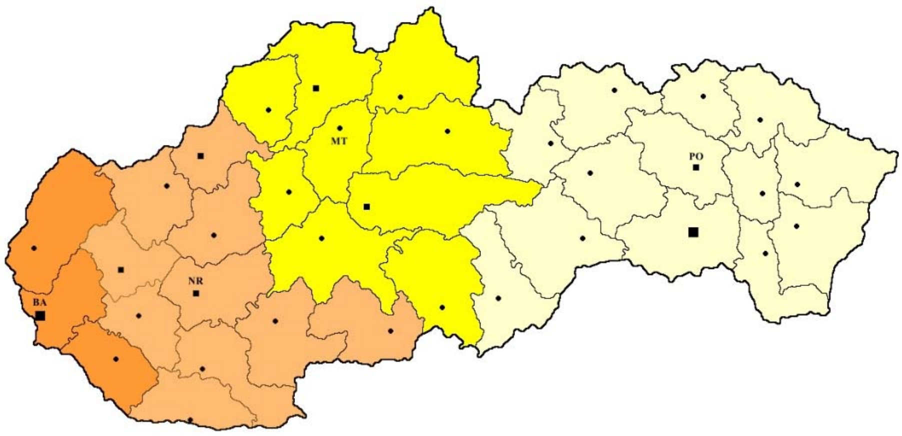

Figure 10. Allocation of four centers in Variant – distance model

5. Conclusions

The results of the application p-median allocation model on the underlying network graph (where the edges were variantly weighted by the travel time and the metric distance) bring some interesting findings.

In the case of allocating a single main centre in the postal transportation network, it is not important if we take into consideration the travel time or the distance for weighting the graph edges. In both cases we find at the location of the main centre to node Žiar nad Hronom.

When we want to allocate two main centres in the variantly constructed postal transportation network we will reach the different results. The location of the main centre at the to node Nitra (the edges weighted by the metric distance) is due to the advantageous geographic location of the node Nitra in its attraction area and location of the main centre at the node Trnava (the edges weighted by the travel time) is due to the most comfortable position of the node Trnava regards the transport infrastructure (mainly the highway) in the attraction area. Location of the main centre at the node Prešov is given by its position in the graph (Prešov is located in the geographical centre of the region) and also by its good access to the highway.

In the case of the three main centres allocation we can see a clear impact of a better infrastructure on the location of the main centres. In the time variant, the edges weighted by the travel time between the neighbouring nodes of graph resulting in enlarging the attraction area in places where exist a higher quality transport infrastructure (highways existence), and for the distance variant is visible centrist location of the main node Prievidza within its attraction area.

By searching four or more main centres in the network graph we reach the same result (allocation of the centres) for both variants. A very interesting finding of this research is that the maximal covering distance in the variants of four centres is equal or higher than in the variants of three centres. It means that allocation of three high level centres in the conditions of the Slovak republic is optimal.

Table 1. Summary of time/distance optimization variants

Parameter	Model	Time variant	Distance variant
Average time/distance	1 center allocation	138,56 minutes	151,45 km
Maximal time/distance		296 minutes	314 km
Allocated center		Žiar nad Hronom	Žiar nad Hronom
Average time/distance	2 centers allocation	67,91 minutes	79,36 km
Maximal time/distance		181 minutes	171 km
Allocated centers		Trnava Prešov	Nitra Prešov
Average time/distance	3 centers allocation	51,39 minutes	53,12 km
Maximal time/distance		157 minutes	148 km
Allocated centers		Trnava Martin Prešov	Bratislava Prievidza Prešov
Average time/distance	4 centers allocation	43,88 minutes	43,16 km
Maximal time/distance		157 minutes	150 km
Allocated centers		Bratislava Nitra Martin Prešov	Bratislava Nitra Martin Prešov

In conclusion, we can state that the postal transport network (represented by the network graph), where the edges are weighted by the travel time or the metric distance between the neighbouring nodes, brings different results if we want to allocate more than one and less than four main centres. The difference between the weighing of the edges by distance or time in the network graph to allocate large amounts (more than three) of the main centres in the conditions of the territory similar to the Slovak Republic is disadvantageous.

Generalization of the knowledge gained from the research presented in this article can be concluded as follows: ***the choice of the optimization criteria of postal transportation network is dependent on the size and character of the territory*** (where takes place optimization) ***and optimization parameters*** (mainly covering distance of the attraction area).

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VEGA 1/0515/15 - Endogenous factors of the IPR intensive Industries in the regional enterprise environment in the Slovak Republic (Endogénne faktory v odvetviach náročných na ochranu duševného vlastníctva v regionálnom podnikateľskom prostredí v SR)

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CUMULATIVE INDEX

TRANSPORT and TELECOMMUNICATION, volume 16, no. 3, 2015 (Abstracts)

Hilmola, O.-P., Tolli, A. Early 2015 Performance in Baltic Sea Ports: Forecasts of Estonian Performance for Entire Year, *Transport and Telecommunication*, vol. 16, no. 3, 2015, pp. 183-189.

Many changes have appeared in year 2015. In Europe economic malaise has continued since debt crisis started in year 2010, and although its effects on Northern Europe have started to diminish, new economic dark clouds have appeared through sanctions set by both European Union and Russia to each other during year 2014. Together with these, shipping sector has been under pressure due to strict sulphur regulation implemented from early 2015 onwards in the entire Baltic Sea Region. Due to these factors, sea ports at Baltic Sea have been under pressure during the first months of 2015, this particularly concerning container handling. Based on our regression model forecast, Estonia and Port of Tallinn shall have clearly declining container handling year ahead. However, overall handling at sea port is not so easy to forecast.

Keywords: Baltic Sea, crisis, sea ports, handling, TEU

Gertsbakh, I. B. Mixed Vehicle Flow at Signalized Intersection: Markov Chain Analysis, *Transport and Telecommunication*, vol. 16, no. 3, 2015, pp. 190-196.

We assume that a Poisson flow of vehicles arrives at isolated signalized intersection, and each vehicle, independently of others, represents a random number X of passenger car units (PCU's). We analyze numerically the stationary distribution of the queue process $\{Zn\}$, where Zn is the number of PCU's in a queue at the beginning of the n-th red phase, $n \to \infty$. We approximate the number Y_n of PCU's arriving during one red-green cycle by a two-parameter Negative Binomial Distribution (NBD). The well-known fact is that $\{Zn\}$ follow an infinite-state Markov chain. We approximate its stationary distribution using a finite-state Markov chain. We show numerically that there is a strong dependence of the mean queue length $E[Zn]$ in equilibrium on the input distribution of Y_n and, in particular, on the "over dispersion" parameter $\gamma = Var[Y_n]/E[Y_n]$. For Poisson input, $\gamma = 1$. $\gamma > 1$ indicates presence of heavy-tailed input. In reality it means that a relatively large "portion" of PCU's, considerably exceeding the average, may arrive with high probability during one red-green cycle. Empirical formulas are presented for an accurate estimation of mean queue length as a function of load and g of the input flow. Using the Markov chain technique, we analyze the mean "virtual" delay time for a car which always arrives at the beginning of the red phase.

Keywords: signalized traffic light, Markov chain, average queue length, mixed vehicle input flow, negative binomial distribution, over dispersed input, virtual delay

Skoglund, T., Wallgren, P., Karlsson, M., Franzén, S. Users' Perception and Reported Effects of Long-Term Access to In-Vehicle Traffic Information Services Mediated Through Nomadic Devices. Results from a large-scale inter-European field operational test, *Transport and Telecommunication*, vol. 16, no. 3, 2015, pp. 197-206.

ICT-mediated traffic information has been argued to contribute to a more sustainable transport system through affecting drivers. Nevertheless, long-term effects of travellers having access to nomadic in-vehicle systems for traveller information are not well known. This study presents the results from a multi-national large-scale field operational test (FOT). The results show that the users in general were positive to the tested systems and that there were several effects on their driving behaviour but in many cases the effects were limited. Moreover the effects varied between system types. Positive effects were related to comfort, as well as individual and system efficiency. One could also notice that perceived effects were not as high as the participants had expected, leading to some disappointment. Most of the times this was due to the tested systems functioning in a less than optimal way.

Keywords: field operational test, traffic information, nomadic device

Nežerenko, O., Koppel, O. Formal and Informal Macro-Regional Transport Clusters as a Primary Step in the Design and Implementation of Cluster-Based Strategies, *Transport and Telecommunication*, vol. 16, no. 3, 2015, pp. 207-216.

The aim of the study is the identification of a formal macro-regional transport and logistics cluster and its development trends on a macro-regional level in 2007-2011 by means of the hierarchical cluster analysis. The central approach of the study is based on two concepts: 1) the concept of formal and informal macro-regions, and 2) the concept of clustering which is based on the similarities shared by the countries of a macro-region and tightly related to the concept of macro-region. The authors seek to answer the question whether the formation of a formal transport cluster could provide the BSR a stable competitive position in the global transportation and logistics market.

Keywords: Baltic Sea Region (BSR), hierarchical cluster analysis (statistics), location quotient, macro-region, transport and logistics

Krainyukov, A., Kutev, V. Employment of IGBT-Transistors for Bipolar Impulsed Micro-Arc Oxidation, *Transport and Telecommunication*, vol. 16, no. 3, 2015, pp. 217-223.

The paper is devoted to the use of insulated gate bipolar transistors (IGBT) for the micro-arc oxidation (MAO) process. The technical requirements to the current switches of power supplies for the pulsed bipolar MAO technology have been developed. The research installation for investigating the IGBT commutation processes during the pulse anode-cathode oxidation has been constructed. The experiments have been performed with its help in order to estimate the possibility of using half-bridge IGBT-modules with different drivers. The research results of the commutation processes investigation for different IGBT half- bridge modules are presented.

Keywords: micro-arc oxidation, insulated gate bipolar transistors, high voltage, commutation process, ballast resistance

Collotta, M., Pau, G. New Solutions Based on Wireless Networks for Dynamic Traffic Lights Management: A Comparison between IEEE 802.15.4 and Bluetooth, *Transport and Telecommunication*, vol. 16, no. 3, 2015, pp. 224-236.

The Wireless Sensor Networks are widely used to detect and exchange information and in recent years they have been increasingly involved in Intelligent Transportation System applications, especially in dynamic management of signalized intersections. In fact, the real-time knowledge of information concerning traffic light junctions represents a valid solution to congestion problems. In this paper, a wireless network architecture, based on IEEE 802.15.4 or Bluetooth, in order to monitor vehicular traffic flows near to traffic lights, is introduced. Moreover, an innovative algorithm is proposed in order to determine dynamically green times and phase sequence of traffic lights, based on measured values of traffic flows. Several simulations compare IEEE 802.15.4 and Bluetooth protocols in order to identify the more suitable communication protocol for ITS applications. Furthermore, in order to confirm the validity of the proposed algorithm for the dynamic management of traffic lights, some case studies have been considered and several simulations have been performed.

Keywords: wireless sensor networks; road monitoring; traffic lights; intelligent transportation systems

Madleňák, R., Madleňáková, L., Štefunko, J. The Variant Approach to the Optimization of the Postal Transportation Network in the Conditions of the Slovak Republic, *Transport and Telecommunication*, vol. 16, no. 3, 2015, pp. 237-245.

The optimizing process of the postal transportation network can be based on several variables and on different infrastructures. The most commonly used variables for optimization are time and distance. This article is focused on the comparison of the results of the optimization process based on the time and distance variables in the conditions of the Slovak national postal operator.

The different types of the underlying infrastructures (roads or railways) could be used for optimization based on the territory conditions. For the optimization, there has been used the p-median method, that describes the problem of locating P "facilities" relative to a set of "customers" in such a way that the sum of the shortest demand weighted distance between "customers" and "facilities" is minimized.

In the conclusion, the article authors will formulate the rule for selection of the best optimization variables for the postal transportation network optimization.

Keywords: optimization, postal transportation network, distance, time, infrastructure, p-median

TRANSPORT and TELECOMMUNICATION, 16. sējums, Nr. 3, 2015 (Anotācijas)

Hilmola, O.-P., Tolli, A. Baltijas jūras ostu sniegums 2015. gada sākumā: Igaunijas snieguma prognoze visam gadam, *Transport and Telecommunication*, 16. sējums, Nr. 3, 2015, 183.-189. lpp.

2015. gadā ir parādījušas daudzas izmaiņas. Eiropas ekonomikas vājums ir turpinājies kopš parādu krīzes sākuma 2010. gadā un, lai gan tās ietekme uz Ziemeļeiropu ir sākusi samazināties, 2014. gadā laikā jaunie tumšie ekonomikas mākoņi ir parādījušies caur noteiktajām sankcijām vienam pret otru gan no Eiropas puses, gan no Krievijas puses. Līdz ar to kuģniecības nozare ir zem spiediena stingro regulu dēļ, kuras tiek īstenotas no 2015. gada sākuma visā Baltijas reģionā. Sakarā ar šiem faktoriem Baltijas jūras ostas pirmajos 2015. gada mēnešos ir zem spiediena un tas jo īpaši attiecas uz konteineru pārkraušanu. Pamatojoties uz mūsu regresijas modeļa prognozi, Igaunijas un Tallinas ostās būtiski samazināsies konteineru pārkraušana gadu uz priekšu. Tomēr kopumā pārkraušanu jūras ostās nav tik viegli prognozēt.

Atslēgvārdi: Baltijas jūra, krīze, jūras ostas, pārkraušana, TEU

Gertsbakh, I. B. Jauktā transportlīdzekļu plūsma pie signalizētajiem krustojumiem: Markova ķēdes analīze, *Transport and Telecommunication*, 16. sējums, Nr. 3, 2015, 190.-196. lpp.

Mēs pieņemam, ka Puasona process transportlīdzekļu plūsma parādās izolētajos signalizētajos krustojumos un katrs transportlīdzeklis, neatkarīgi no citiem, ir nejaušs skaitlis X pasažieru automobiļu skaits (PCU's). Mēs analizējam stacionāro skaitlisko sadalījumu rindu procesā $\{Zn\}$, kur Zn ir PCU skaits rindas sākumā no *n-tās* sarkanās fāzes, $n \to \infty$. Mēs tuvinām skaitli Yn no PCU, kas ierodas vienā sarkanā-zaļā ciklā, par Negatīvo Binomu Sadales (NBD) diviem parametriem. Labi zināms fakts ir tas, ka $\{Zn\}$ seko Markova ķēdes bezgalīgais stāvoklis. Mēs tuvinām tā stacionāro sadalījumu, izmantojot Markova ķēdes ierobežoto stāvokli. Mēs skaitliski parādām, ka pastāv spēcīga atkarība no vidējās rindas garuma $E[Zn]$ līdzsvarā no datu izplatīšanas no Y_n un, jo īpaši no „ virs dispersijas" parametrs $\gamma = Var[Y_n]/E[Y_n]$. Puasona process $\gamma = 1$. $\gamma > 1$ norāda uz smagu astu klātbūtni. Patiesībā tas nozīmē, ka salīdzinoši liela daļa no PCU var krietni pārsniegt vidējo un ierasties vienā sarkanā-zaļā ciklā. Empīriskās formulas ir uzrādītas, lai precīzi novērtētu vidējās rindas garumu atkarībā no slodzes g ievades plūsmā. Izmantojot Markova ķēdes tehniku, mēs analizējam vidējo „virtuālo" aiztures laiku mašīnai, kas vienmēr ierodas sarkanās fāzes sākumā.

Atslēgvārdi: signalizētās satiksmes gaismas, Markova ķēde, vidējais rindas garums, jaukta transportlīdzekļu ieejas plūsma, negatīvā binominālā izplatīšanās, pār izkliedētā izplatīšana, virtuālā aizture

Skoglund, T., Wallgren, P., Karlsson, M., Franzén, S. Lietotāju uztvere un ziņojumu ilgtermiņa ietekmes pieeja uz transportlīdzekļu satiksmes informācijas dienestu realizāciju caur pārnēsājamajām ierīcēm. Rezultāti no liela mēroga Eiropas starpnozaru praktiskās darbības pārbaudes. *Transport and Telecommunication*, 16. sējums, Nr. 3, 2015, 197.-206. lpp.

ICT starpniecību satiksmes informācija tika apspriesta, lai veicinātu stabilāku transporta sistēmu, ietekmējot vadītājus. Neskatoties uz to ceļotāju ilgtermiņa ietekme, kuriem ir pieeja pārnēsājamajām transportlīdzekļu ierīcēm ceļotāju informācijai, ir maz zināma. Pētījumu uzrāda rezultātus no liela mēroga daudznacionālās praktiskās darbības pārbaudes (FOT). Rezultāti liecina, ka lietotāji kopumā bija pozitīvi vērsti uz pārbaudīto sistēmu un ka tur bija vairāki faktori, kuri ietekmēja braukšanas stilu, bet daudzos gadījumos sekas tikai ierobežotas. Turklāt ietekmē svārstījās starp sistēmu tipiem. Pozitīvā ietekme tika saistīta ar komfortu tāpat, kā ar individuālu un sistēmas efektivitāti. Kā arī ir bija redzams rezultāti nebija tik augsti, cik to gaidīja dalībnieki, kas noveda pie vilšanās. Lielākoties tas bija saistīts ar mazāku sistēmas funkcionēšanu nekā optimālajā veidā.

Atslēgvārdi: praktiskās darbības pārbaude, satiksmes informācija, pārnēsājamās ierīces

Nežerenko, O., Koppel, O. Formālās un neformālās makroreģionālie transporta klasteri kā primārais solis uz klasteru balstīto stratēģiju projektēšanu un īstenošanu, *Transport and Telecommunication*, 16. sējums, Nr. 3, 2015, 207.-216. lpp.

Pētījuma mērķis ir identificēt formālās makroreģionālās transporta un loģistikas klasterus, un to attīstības tendences makroreģionālajā līmenī 2007.-2011. g., izmantojot hierarhisko klasteru analīzi. Pētījuma galvenā pieeja balstās uz diviem konceptiem: 1) formālo un neformālo makroreģionu koncepts un 2) klasteru jēdziens, kas ir balstīts uz līdzībām, kuras piemīt valstīm no makroreģioniem un stipri saistītām ar makroreģionu konceptu. Autori cenšas atbildēt uz jautājumu, vai formālo transporta klasteru izveide varētu nodrošināt Baltijas jūras reģionam stabilu konkurētspējīgu pozīciju globālajā transporta un loģistikas tirgū.

Atslēgvārdi: Baltijas jūras reģions (BJR), hierarhiskā klasteru analīze, atrašanās vietas faktors, makroreģions, transports un loģistika

Krainyukov, A., Kutev, V. IGBT tranzistoru nodarbināšana bipolārai mikroloka oksidēšanai, *Transport and Telecommunication*, 16. sējums, Nr. 3, 2015, 217.-223. lpp.

Pētījums ir veltīts bipolāro tranzistoru izolētas pārejas izmantošanai mikroloka oksidēšanas (MAO) procesam. Bija izstrādātas tehniskās prasības esošajiem barošanas bloku slēdžiem bipolārai impulsa MAO tehnoloģijai. Pētījuma uzstādīšana tika konstruēta, lai izpētītu IGBT komutācijas procesus impulsa anoda-katoda oksidēšanas laikā. Ar to palīdzību tika nodemonstrēti eksperimenti, lai varētu novērtēt pustiltu IGNT moduļu izmantošanas iespēju ar dažādiem draiveriem. Komutācijas procesu izpētes rezultāti dažādiem IGBT pustiltu moduļiem tiek prezentēti.

Atslēgvārdi: mikroloka oksidēšana, izolētas pārejas bipolāri tranzistori, augstspriegums, komutācijas process, balasta pretestība

Collotta, M., Pau, G. Jauni risinājumi dinamisko luksoforu vadībai, kuri balstās uz bezvadu tīkliem: salīdzinājums starp IEEE802.15.4 un Bluetooth, *Transport and Telecommunication*, 16. sējums, Nr. 3, 2015, 224.-236. lpp.

Bezvadu sensora tīkli tiek plaši izmantoti, lai atrastu un apmainītu informāciju, un pēdējo gadu laikā ievērojami tiek iesaistīti Intelektuālās Transporta Sistēmu programmās, īpaši signalizēto krustojumu dinamiskajā vadībā. Faktiski, reālā laika informācijas zināšanas par luksofora krustojumiem atspoguļo derīgu risinājumu sastrēgumu problēmu atrisināšanai. Šajā darbā, bezvadu tīkla arhitektūra, kas balstās uz IEEE 802.15.4 vai Bluetooth, tiek ieviesta, lai atsekotu transporta plūsmu blakus luksoforiem. Turklāt, tiek piedāvāts, inovatīvs algoritms, lai noteiktu dinamiski zaļās gaismas laikus un luksoforu secības fāzi, kas balstās uz satiksmes plūsmas izmērītām vērtībām. Vairākas simulācijas salīdzina IEEE 802.15.4 un Bluetooth protokolus, lai varētu identificēt atbilstošāku komunikācijas protokolu ITS programmām. Turklāt, lai apstiprinātu piedāvātā algoritma derīgumu luksoforu dinamiskajai vadībai, vairāku problēmsituāciju analīze bija izskatīta un tika veiktas vairākas simulācijas.

Atslēgvārdi: bezvadu sensora tīkli, ceļu monitorings, luksofori, intelektuālā transporta sistēmas

Madleňák, R., Madleňáková, L., Štefunko, J. Varianta pieeja Pasta transporta tīkla optimizācijai uz Slovākijas Republikas parauga, *Transport and Telecommunication*, 16. sējums, Nr. 3, 2015, 237.-245. lpp.

Pasta transporta tīkla optimizācijas process balstās uz vairākiem mainīgajiem un dažādām infrastruktūrām. Visvairāk izmantotas mainīgās vērtības optimizācijas procesam ir laiks un attālums. Šis darbs ir fokusēts uz rezultātu salīdzināšanu par optimizācijas procesu, kas balstīts uz tādiem mainīgajiem kā laiks un attālums uz Slovākijas nacionālā pasta operatora parauga.

Dažādi infrastruktūras veidi (ceļi vai dzelzceļi) varētu būt izmantoti optimizācijas procesā, balstoties uz teritorijas stāvokli. Optimizācijai bija izmantota p-mediānas metode, kura paskaidro P ”objektu” atrašanās vietas attiecībā pret “klientu” kopumu problēmu tādā veidā, ka no īsākā pieprasījuma svērto attālumu summa starp "klientiem" un "objektiem" ir minimāla.

Noslēgumā, šī darba autori noformulēs noteikumus labāku mainīgu izvēlei pasta transporta tīkla optimizācijai.

Atslēgvārdi: optimizācija, pasta transporta tīkls, attālums, laiks, infrastruktūra, p-mediāna

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