Border-Crossing Points; modelling of waiting queues; traffic simulation

Mihaela POPA*, Eugen ROSCA, Florin RUSCA, Dorinela COSTESCU, Vasile DRAGU
University POLITEHNICA of Bucharest, Transport Faculty
Spl. Independentei, 313, 060042, Bucharest, Romania
**Corresponding author*. E-mail: mihaela.popa@upb.ro

TRANSIT TIME THROUGH THE BORDER-CROSSING POINTS: THE CASE STUDY OF THE EU'S ROAD BCP WITH MOLDAVIA

Summary. This paper provides an overview on the ACROSSEE project (funded by the ERDF under the SEE program), its objectives, general methodology, and the main results. Moreover, the main survey results are presented as they relate to the Romanian road and rail border-crossing points (BCPs) with the Eastern neighbourly country, Moldavia. Results include the actual status of the road BCP, surveys on exiting and entering traffic flows, answers to specific questionnaires of the truck and car drivers in relation with origin-destination of the trips, average waiting time in queue and time required for procedures and controls. Discussion on the mathematical modelling is presented and a provisional simulation model is developed, using ARENA software. The early results are used in order to introduce the need for future assessment of the transit time in a road BCP, with the main purpose: the substantiation of the strategic and operational actions for improvements in trade and transport crossings of the EU borders, considering the need for more vigilant and less time-consuming checks at the outside borders of the EU.

TEMPS DE TRANSIT À TRAVERS LES POINTS DE PASSAGE FRONTALIERS: L'ÉTUDE DE CAS POUR LA LIAISON ROUTIÈRE ENTRE ROUMANIE ET MOLDAVIE

Résumé. Ce papier donne un aperçu sur le projet ACROSSEE (financé par le FEDER dans le cadre du programme SEE), ses objectifs, la méthodologie générale, et les principaux résultats; en outre,les principaux résultats de l'enquête sont présentés en rapport avec les points routiers et ferroviaires de passage frontaliers (PPF) entre Roumanie et Moldavie. Les résultats comprennent l'état actuel du PPF de la route; enquêtes sur la sortie et l'entrée des flux de trafic; réponses aux questionnaires spécifiques des chauffeurs de camions et de voitures en relation avec l'origine-destination des voyages; le temps moyen d'attente et le temps nécessaire pour accomplir les procédures du contrôle. Discussion sur la modélisation mathématique est présentée et un modèle de simulation prévisionnel est développé, en utilisant le logiciel ARENA. Les premiers résultats sont utilisés afin d'introduire la nécessité d'une évaluation ultérieure du temps de transit par un PPF routier, ayant comme objectif principal la justification des actions stratégiques et opérationnelles pour des améliorations dans le commerce et le transport franchissant les frontières de l'UE, compte tenu de la nécessité d'un contrôle plus vigilant et habituellement long à la frontière extérieure de l'UE.

1. INTRODUCTION

Border crossings play an important role in transport and trade all over the world because of the time spent for different procedures of checking or particular screenings, depending on the geopolitical status of the bordering countries, but also depending on the technological level of development of the facilities and transport infrastructure for those procedures.

Border crossing procedures depend on the geopolitical location of the economic territories and, hence, there are very particular conditions for their analysis and improvement actions. In literature, this is reflected in various typology of studies. A much-documented study delivered by the OSCE-UNECE provides a comprehensive list of the international legal frameworks on trade and customs, separately on the World Trade Organization, the World Customs Organization, and other types of configuration and trade agreements [11]. An overview of the Coordination Border Management and Collaborative Border managements with several cases provides information and added value of the document. The American/Canadian cross-border issues are the subject of several studies. Using four data sources for comparison—a GPS freight carrier border delay data set, a commercial volume data set, a detailed border operations survey data set and manifest sampling—a detailed analysis considers the linkages among volume, delay, border operations, commercial vehicle origin and destination, and commodities carried to create a commercial vehicle profile at the primary border crossing along the Western Cascade border region of southwest British Columbia, Canada, and northwest Washington, United States. The understanding of this profile should aid in the development of solutions to mitigate border delay and its impacts [4 - 6]. It was found that the information and communication technology (ICT) and intelligent transport systems (ITS) have importance in harmonising and standardising cross-border procedures, thereby improving the logistics systems [10, 14].

In a 2007 study on cross-border trade within the Central Asia Regional Economic Cooperation [17], the World Bank reveals that this trade and its cross-border conditions play an important role in supporting the livelihoods of border communities, thereby buttressing prosperity in central Asia. Furthermore, by strengthening commercial ties, promoting cultural understanding, and deepening community relationships, cross-border trade helps to nurture amicable relations between neighbours.

The Cross-Border Transport Infrastructure research series performed by JICA [7] focused on the sub-Saharan Africa area, including the systems and infrastructure in East Africa. Based on these analyses future directions for that area were presented. The European policy for transport infrastructure is concentrated to the completion on TEN-T corridors, with special attention for cross-border links in order to obtain the full-integrated and multimodal connection around Europe at the 2020 horizon [2].

All studies point out the importance of connecting territories by adequate transport infrastructure and by *smooth transit for trade and transport.* However, *the deep modelling for the purposes of investment decision-making is not fully developed,* up to now.

In the matter of analysis of the transport flows crossing borders, there are a few references and the main results are related to finding the explanatory variable of the cargo flow increase, as for example, the cargo flows between Texas and Mexico, using large data series in time and ARIMA analysis [3]. A deep analysis of traffic flows and their dynamic queues usually addressed to the urban congestion and its influence on traffic accidents [9], but no consideration on features of the crossing border flows was found.

In this paper, we consider the results of the EU project ACROSSEE and propose a simulation model for the road cargo traffic flows exiting to the outside of the EU territory, to Moldavia. The aim is to develop a useful decision-making tool for investment needs in border-crossing points. For this, we selected the main findings of the ACROSSEE project in case of the road BCP Vama Albita, which have an important role in trade and transport activities between Romania/EU and the Republic of Moldavia, inside the European Neighbourhood Policy. Starting with the results of the two performed surveys on the road cargo traffic flows and border-crossing procedures, we discuss on a queue mathematical model and propose a simulation model in order to estimate the total transit time in different conditions. The very early results of the simulation model reveal the need for the further modelling research and for the additional data in order to support a more realistic simulation of different strategic actions for border crossing. The paper is organised as follows. In the next section the

main findings of the ACROSSEE projects are described. Then, in the third section, the description of the traffic flows and the procedure in a selected road BCP between EU/Romania and Moldavia is provided. The fourth section is dedicated to an overview of the known queue theory in order to find the most appropriate mathematical model for traffic flows through a road border crossing point. Their insufficient inadequacy to the specificity of the traffic flows in a BCP leads to the development of a simulation model, which is proposed in the fourth section and the main conclusions are drawn in the final section.

2. MAIN RESULTS OF THE EU FUNDED PROJECT ACROSSEE

During the last EU programming period 2007-2013, there were several programs aiming at the EU regional development policy implementation as the South East Europe (SEE) Transnational Cooperation Programme, in which the third Priority was dedicated to the Improvement of Accessibility.

The ACROSSEE project "*Accessibility improved at border CROSsings for the integration of South East Europe*" has been developed under the mentioned priority and was carried out between 2012 and 2014; its large SEE consortium was led by the Central European Initiative, from Trieste, Italy.

The main added values of the project are related to: 1- the analysis and reporting of the assessment of available infrastructure capacity—rail and road—with a focus on bottlenecks, and geographical presentation of bottlenecks: identification of the main international routes for goods circulation; assessment of how present supply meets demand; identification of where and how substantial improvements in transport can be obtained through better services before relevant infrastructure improvements—through short-term policies; 2- an analysis of the market potentials and trends in relation with the Trans-European Transport Networks revised policy and the overall European Neighbourhood Policy, namely, the priority (core and comprehensive) networks, their extensions, and the trade flows having origin and destination from or to the neighbouring countries and regions (Moldavia, Ukraine, the former Yugoslavia countries and Turkey). These trends were analysed through the evaluation of the impact of the trans-European Transport network revision and the optimisation of the TEN-T networks and through the simulation of future scenarios for examining the potential growth of trade. The analysis referred to the performance of the border crossing points in order to define the required interventions or measures.

The different types of surveys were performed, such as surveys on the procedures in selected BCPs, surveys on the car drivers for the origin-destination analysis, surveys on the truck drivers, for multiple purposes, traffic surveys on the route near to and from the selected BCPs (fig. 1) [14].

Direct field surveys on rail and road cross-border stations were performed in order to define a map of the border-crossing total time transit. Questionnaire-based surveys pursuing a common methodology were carried out at railway agency, rail operators, rail safety regulators, safety and security agencies, freight forwarders and phytosanitary offices.

The surveys addressed to commercial vehicle drivers at BCPs contributed to the drawing up of the extension of long distance road routes in SEE. The questionnaire included information on the origin and destination of the trip, transit frequency, average distance covered, travel times, speed average; the outcomes of interviews provided inputs for detailing the transport model, which was performed in a dedicated work package. For the same purpose of developing a transport model for the SEE region, the traffic surveys to and from selected BCPs were performed during a carefully selected period of the year, in 2013.

The outcomes of the BCP analysis led to the identification of existing infrastructure and administrative bottlenecks limiting the goods circulation in SEE. The survey on the type of goods has been confronted with the existing routes in the logistic chain and its potential efficiency.

Based on the results of the surveys and the analysis of applied practices at BCPs, ACROSSEE defined a package of proposed *short-term measures per BCP and horizontal policies for border management in South East Europe* (mostly Cohesion Fund countries), which would not require significant investments by the national governments and their results could be tangible in the short term [14].
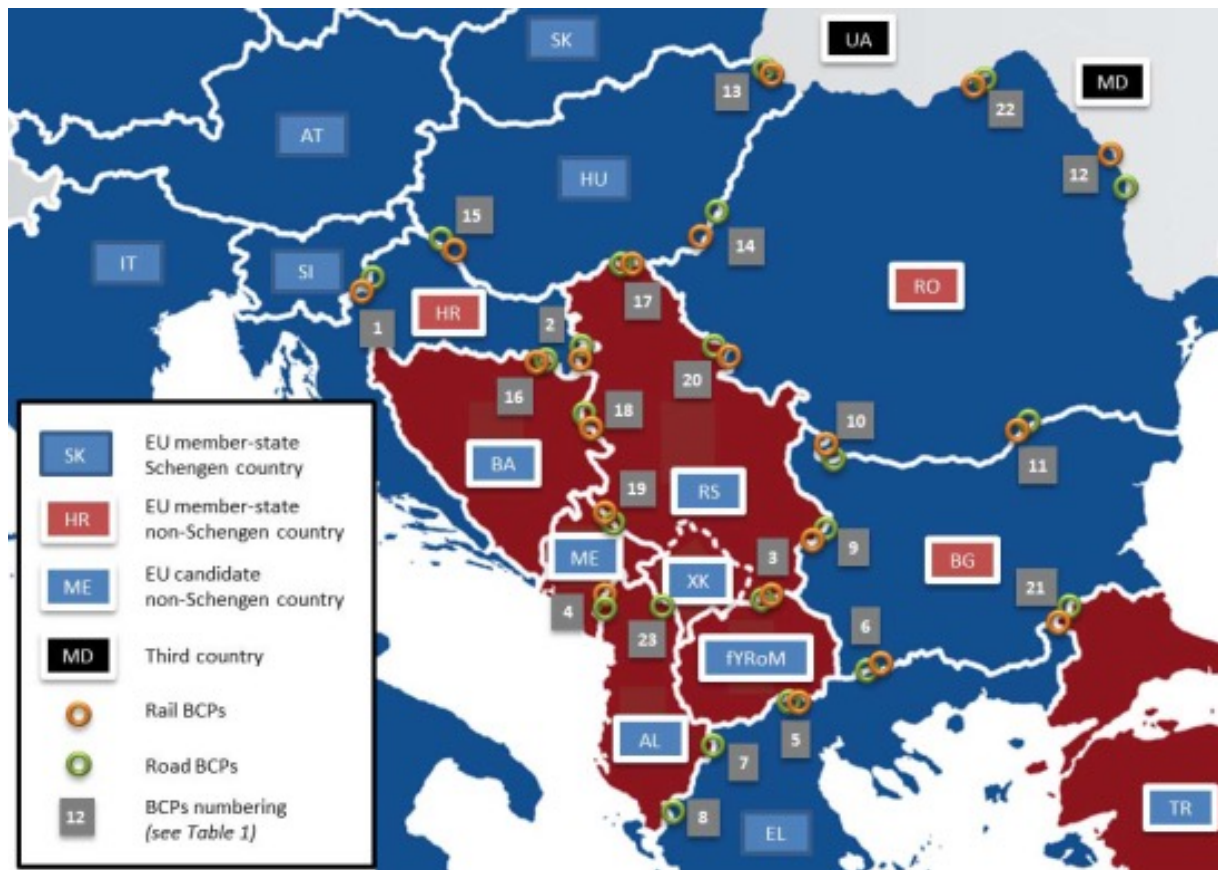
Fig. 1. The location of the surveyed road and rail BCPs [18]
Fig. 1. Emplacement des PPF routières et ferroviaires [18]

Interventions, measures and investments *have short-, mid- and long-term character* so that they correspond with the status of pre-accession, accession and full integration of Western Balkans and the Southeast and East European countries into the EU and the Schengen area.

According to the analysis of the existing infrastructure in SEE, main problems are currently met along the railway network, rather than on the road network where capacity problems are present only at specific links and mainly around major urban centres.

Overall border crossing times represent 14% to 25% of the total travel time, depending on the number of border crossings along each route. The estimated commercial speeds along the respective road routes around the ACROSSEE area of study vary between 30 and 65 km/h.

In other selected origin-destination pairs analysed in the region (transit from/ to Ukraine/ Moldavia/ Turkey), nineteen in total and mainly for road but also rail and maritime transport, *the percentage of time spent at borders is on average 10,5% of the total travel time.*

There are different reasons concerning problems with the existing facilities and equipment, public utilities, communication systems, documentation, operating hours, insufficiency of staff (in terms of number, competencies and behaviour), and other organisational, administrative and management problems related to poor coordination of intra-agency, inter-agency and bilateral cooperation.

3. THE ROAD BCP AT THE EASTERN BORDER OF ROMANIA/ EU

A major issue during the planning of the surveys was the different status of the various SEE countries (EU member state, Schengen Treaty country, non-EU member state). In a case of two bordering Schengen countries, only traffic flows data could be collected since stops are not obligatory and no permanent controls are performed at those border points. In a case of two neighbouring non-Schengen countries or of an EU country or a Schengen country with a non-EU country, the entire set

of surveys had been implemented. As a result, the surveys were performed, in total, at 59 road and rail BCPs (see above fig. 1).

The surveyed road BCP with Moldavia was *Vama Albita* which is located at the eastern border between Romania and Moldova (in the northern part of the Galati Port on the Danube River) and started in 1974.

The road BCP is equipped with six lanes at the entrance and seven at the exit serving different types of vehicles. Their utilisation is separated for EU and non-EU vehicles, and one line for each direction is restricted for priority movements, for example, for diplomatic purposes.

The main facilities, their status and available staff for border procedures are presented in Table 1. The findings related to the time needed for performing the procedures are in Table 2. The traffic characteristics reported during the surveyed time were passenger vehicles (mostly cars) -70%, buses - 2%, commercial vehicles (mostly trucks) -28%. The average occupancy of the passenger vehicles is 3 passengers.

Table 1

The main facilities in the road BCP Vama Albita

Facility/ building	Status of facility	Total Staff number-working time	Other
Border Police	good condition	60 - 24/7	telephone; internet; surveillance cameras;
Border Custom Agency	good condition	60 - 24/7	X-Ray machine; weighbridge
Phytosanitary Agency	good condition	3 - 12	no mobile laboratory
Veterinary Agency	good condition	24- 8	telephone; internet
Facility of the National Road Administration for vignette sell	new building	38/24 h	telephone; internet
Other facilities: coffee-shop; currency exchange office; ATM	good condition	-	-

Table 2

Times for controls and waiting time in queues [min] in Vama Albita road BCP

Type of vehicles	Cars	Buses	Trucks
Time for performing controls: min/average/maximum for the country -exiting flows			
Police	1/3/60	15/20/120	15/34/480
Border Custom Agency	1/3/30	3/10/20	15/20/25
Phytosanitary Agency	-	-	20/60/280
Veterinary Agency			15/60/240
Time for performing controls: min/average/maximum for the country -entering flows			
Police	1/5/120	20/25/180	10/30/360
Border Custom Agency	1/6/100	15/30/120	20/40/60
Phytosanitary Agency	-	-	20/60/280
Veterinary Agency	-	-	20/60/240
Waiting time in queue for the country exiting flows			
-	0/7/180	0/15/120	0/30/600

During the survey, drivers of the commercial vehicles entering the BCP were asked to answer and 158 questionnaires were filled. The share of drivers answering the questionnaires by their direction was 60% from the total country-entering traffic who filled the questionnaires; 85% from the total country-exiting traffic filled the questionnaires. The several commercial traffic characteristics were as follows: vehicles with empty of cargo is 32%; vehicles transferring plants and vegetables is 1%; vehicles transferring live animals is 10%; vehicles under the TIR carnet is 30%.

The time intervals for controls have a large variation depending on the commodity and passenger condition and the entering seems to take more time than exiting, which might suggest more rigorous controls or, on the contrary, more problematic issues occurring on entering the EU territory. The

waiting time in queues has also a large variation, which might suggest a large variation in traffic flows for both directions and lack of flexibility (adjusting) in control capacities. A deeper analysis and accurately based-modelling, in order to cut the both categories of the time spent in the BCPs, should be the basic part of a future substantiated development or modernising plan and associated ranking list.

It is worth mentioning that during 2009 and 2010, Schengen evaluation missions in Romania were organised in order to verify on the spot the implementation of the Schengen acquis in the following fields: police cooperation, data protection, visas, land, sea and air borders, etc. Following the Schengen evaluation visits on the spot, Schengen evaluation reports were drafted for each field. The main conclusion of the Schengen evaluation reports was that Romania had reached an advanced level in the implementation of the Schengen acquis and was prepared for Schengen accession. Each evaluation report contained the legal, procedural and infrastructure recommendations that Romania must implement before the accession to the Schengen area.

Later on, the third biannual report from the Commission to the European Parliament and the Council of May 2013 mentioned that although Romania, as well as Bulgaria, fulfilled the criteria to apply in full for the Schengen acquis, the implementation of further measures would contribute to their accession [13]. However, even Romania is fully technically prepared for the Schengen area; from the political point of view, several postponements were justified by the EU Parliament.

Considering that in the BCPs with external territory the performed controls and procedures are in full compliance with the Schengen requirements, the discussions on both *the time for procedures and waiting time before procedures* are still open. The delays at BCPs have a negative influence on the efficiency of trade and transport in the EU and regions with external territory, and even more, it might impede on the external strategic policy.

4. MATHEMATICAL MODELLING FOR THE BCP TRANSIT TIME ASSESSMENT

4.1. Basic concepts for a queue system in a stationary regime

There are several modelling considerations to find the most appropriate mathematical queue model for the road traffic serving in a BCP.

The mathematical models for the modelling of the traffic units serving are different, depending on both the characteristics of the entering traffic flows and of the serving stations. A detailed and recent literature review is available in [15]. Synthetically, the Kendall-Lee classification [8] mentions the code *A/B/n:* (*m/D*) facilitating the mathematical models identification. The meaning of that code is well known: *A* is the probability density function of the inter-arrival times of entering flow; *B*—the probability density function of the serving times of the traffic units in a serving station/resource; *n*—the number of identical serving stations which are working simultaneously; *m*—the maximum number of places/spots in a serving system for waiting units; *D*—serving discipline or rule.

If $\lambda << n\mu$, then the waiting time before the serving start is almost zero; otherwise, in case that $\lambda > n\mu$, the waiting times before serving start are significant; in case this situation is maintained for a long time, practically the queues before the serving are continuously growing and no further serving is possible in a future acceptable time horizon.

Despite the suggestion of the name, the stationary regime (as a steady state) is not very easy to define. The assessment of the system's operation in a stationary regime is based on the stability of the specific parameters during the sufficiently large time periods. As it is well-known in cases of waiting or queue systems, the specific parameters are as follows: the average waiting times, $\overline{t}_a$; the average time of serving for a unit (single demand), $\overline{t}_s$; the average number of units in waiting queue, $\overline{n}_a$; the average number of units in the system, $\overline{n}_s$. In a case of the stationary regime and a single serving station (n=1), the specific parameters are related, according to the Little equations [5]. The below eqs. (1) is very useful because it represents a simplified assessment of the serving system operation. In most of the cases, the mathematical models are developed only for the purpose of assessing the average waiting time, $\overline{t}_a$ in queue.

$$\bar{n}_a = \lambda \bar{t}_a; \quad \bar{n}_s = \lambda \bar{t}_s; \quad \bar{t}_s = \bar{t}_a + \frac{1}{\mu}; \quad \bar{n}_s = \bar{n} + \rho; \quad \rho = \frac{\lambda}{\mu} < 1. \tag{1}$$

In case the number of spots in a system is limited, then for the evaluation of the system's operating performance, the probability of rejection needs to be added to the rest of the parameters in (1).

The *rejection probability* represents the probability of a unit to be rejected without being served by the system because it is fully operating and a lot of units are waiting to be served. In a case of the road BCP, because of the significant cost of choosing a different route, the refuse rate might be very low, but further research on this is needed.

4.2. A single serving line with no priority for serving

In the simplest and well-known case of the system with the exponential distribution for both entering and exiting flows, which is described in Kendall-Lee's classification as M/M/1:(∞/FIFO), meaning also that the total number of spots in the system is unlimited and the serving rule or succession is "first-in-first-out", the average waiting time is:

$$\bar{t}_a = \frac{\rho}{1-\rho} \cdot \bar{t}_{sv}, \quad \rho < 1. \tag{2}$$

In road BCPs, the checking procedures have no fixed time depending on different types of road vehicles; as a consequence, the modelled serving process has no regular service (G). The average waiting time, for the serving system M/G/1:(∞/FIFO) according to Kendall-Lee's classification [8], is

$$\bar{t}_a = \frac{\rho}{2(1-\rho)} \cdot \bar{t}_{sv}(1+v_{sv}^2), \quad \rho < 1. \tag{3}$$

where: v_{sv} is the variation coefficient of the serving times, which is defined as a ratio between the standard deviation, $\sigma_{t_{sv}}$ of the serving time of all units and the average serving time for unit/demand, $\bar{t}_{sv} = \frac{1}{\mu}$ (μ is the average intensity of serving).

When the entering flows are mixed (composed of different types of units considering the needed serving time, the waiting time cost, moving conditions and technological conditions or other kinds of particularities, such as the technological process for the passengers or cargo units entering or exiting), for the purpose of efficiency, it is more advantageous to firstly cut the average waiting time through the system. For this purpose of diminishing the overall average cost of transit time through the system, the "expensive" units are replaced from the queue and served separately in order not to disturb the overall transit time too much. This is the case of the special cargo trucks which might need extended time for total checking/screening operation. Special surveys, in order to find the empirical distribution for this event's occurrence, are needed in future research.

4.3. Multiline serving in paralel stations

There are multiple cases for the serving of traffic flows (depending on their distribution of the number of arrivals in a certain unit time, the number of available serving stations, distribution of serving times, serving rule, and the existence or non-existence of cooperation among serving stations), but the developed mathematical models are only for a few and simpler cases.

The largely used distribution of the arrivals in a time interval is the Poisson distribution, which is also used for serving time with a negative exponential distribution of the serving times. Then, the average waiting time in case of *n* parallel serving stations is:

$$\bar{t}_a = \frac{P(k=n) \cdot n\mu}{(n\mu - \lambda)^2}, \quad \text{if} \quad \frac{\lambda}{n\mu} < 1, \tag{4}$$

Probability $P (k = n)$, for the mentioned conditions is:
where: $P(k = n)$ is the probability of the k units inside the system being equal to the total number of serving stations, λ—average rate of the arrivals in the system, μ—average rate of serving at any of the identical serving station, n.

Probability P (k = n) for the mentioned conditions is:

$$P(k = n) = \frac{\rho^n}{n!} P(0),$$ (5)

with $\rho = \dfrac{\lambda}{\mu}$ and $P (0)$ - probability that all the serving station are free (empty), and that is:

$$P(0) = \frac{1}{\displaystyle\sum_{k=0}^{n-1} \frac{\rho^k}{k!} + \frac{\rho^n}{(n-1)!\,(n-\rho)}}.$$ (6)

Graphical representation of the average waiting time function, $\bar{t}_a = f(\rho, n)$, in [12] reveals that for the *low load* (solicitation) on the system, increasing the number of serving stations has a significant influence on the reduction of the average waiting time. On the contrary, when the system is strongly loaded, increasing the number of serving stations is not so important for reduction (cutting) of the average waiting time. Thus, for strong solicitation, that is, for example, $\rho / n = 0{,}8$, increasing the total number of serving stations, *n*, from 1 to 3 (meaning three times) will lead to a diminishing of only 20% of $\bar{t}_a$ [12]. Moreover, the analysis is more complex in the case of *transient serving systems*, which have no continuous 24/7 working time. The additional considerations are needed, because sometimes, for example, during the winter season, the BCP may experience the transient solicitation.

4.4. Disrupted regime of queue system

In a real condition, the BCP operates with a large variation of the entering flows. In rush hours (high solicitation), $\rho > 1$, the queue for serving increases. The queue length has a maximum value at the end of the certain time period t of monitoring, that means

$$n_t = n_0 + \lambda_t t - \mu_t t \;,$$ (7)

where n_0 is the queue at the beginning of period *t* with highest solicitation, λ_t is the average arrival rate during the monitoring time t ($\lambda_t > \lambda$), and μ_t is serving rate during the same congested time, *t* ($\mu_t > \mu$).

After a high solicitation, there is a released time when the queue diminishes, before the other intensive arrival rate starts again. Disrupted regime is quite difficult to be accurately modelled and the simulation is a good solution in this case.

5. SIMULATION MODEL

Using the Arena 11 simulation software, a simulation model is developed in order to assess and analyse the operational parameters in case of a road BCP, considering the available data from performed surveys in Vama Albita. In fig. 2, the number of road vehicles that arrived at a BCP every 15 minutes during one working day in June of 2013 is depicted.
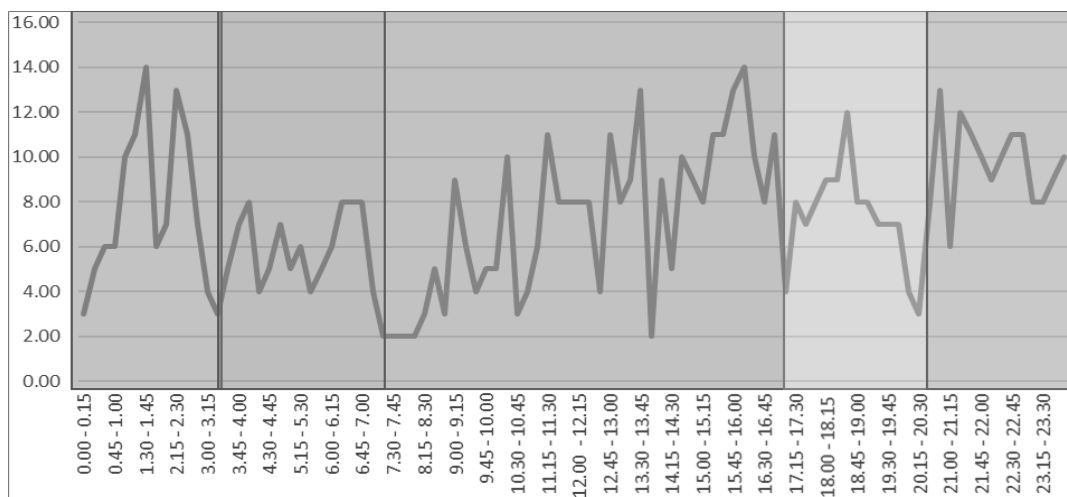
Fig. 2. The number of road vehicles (cars, buses and trucks) that arrived at a BCP every 15 minutes
Fig. 2. Le nombre de véhicules routiers (voitures, autobus et camions) arrivés au PPF, toutesles 15 minutes

Five intervals of times are separated as indicated in fig. 2. The mean of the number of road vehicles is computed and, then, the inter-arrival times are randomly generated around that mean for each of the five-time intervals.

The t-Student test is performed in order to validate the results for the simulated inter-arrival times of the road vehicles. Table 3 contains the results and main parameters.

Table 3

The surveyed data and the t-Student test results for arriving flow

No.	Time Interval	Mean of the surveyed number of vehicles in 15 min	Variance	Used mean of vehicle number	Degree of freedom	Value of t-Student test	Tabular value of t-Student test, α=0.05-significance level
I	0:00-3:15	7.92	3.50	8	12	0.08	2.179
II	3:15-8:15	5.05	2.16	5	19	0.1	2.093
III	8:15-17:00	7.77	3.20	8	34	0.42	2.030
IV	17:00-20:30	7.21	2.33	7	13	0.33	2.16
V	20:30-24:00	9.71	1.86	10	13	0.55	2.16

The simulated values of the inter-arrival times of road vehicles are good enough, as long as for all intervals in the t-Student test are verified.

For the serving process we also randomly generate the procedure times. The normal distribution is used for the procedure time of controls around the declared or perception average of times from survey, for cars, buses and trucks, in respect of the sample share of road vehicles (see figures in Table 2). We note here that the control procedures are not fixed and it depends on the vehicle type, loading, passengers, official documents and papers, etc. The simulation model is developed only for police and custom controls; the phytosanitary and veterinary controls are actually performed during the daytime and need more analyses and considerations for modelling in an interrupted regime. The structure of the simulation model is depicted in fig. 3.

Firstly, the police control is performed and, then, the custom, each time, on all three lines in parallel. The results are synthesised in Table 4. The simulation process runs for different situations of staff involved, starting with the minimum number of 2+2, meaning 2 police officers and 2 customs agents, till the 4+4 involved staff when the waiting time significantly reduces. It is obvious that increasing the control staff will decrease, accordingly, the waiting time in queue. However, the decision related to additional staff employment (by comparison with their costs and the total value of time spent in BCP) requests a substantiated justification.
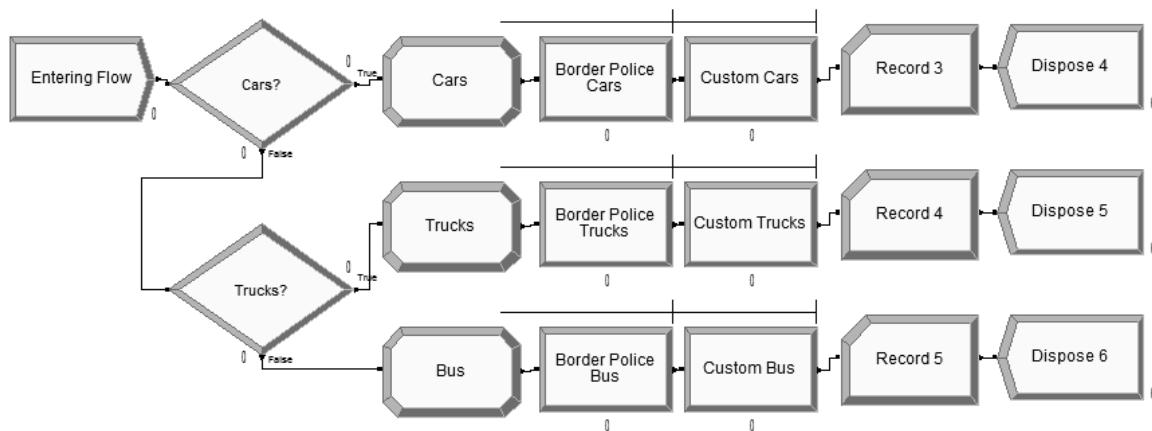
Fig. 3. The structure of the simulation model
Fig. 3. La structure du modèle de simulation

Table 4

Estimated waiting times for cars, buses and trucks, with different combinations of staff numbers

Police control staff	Custom control staff	Waiting time in queue of cars, for police control [min]	Waiting time in queue of busses, for police control [min]	Waiting time in queue of trucks, for police control [min]	Waiting time in queue of cars, for custom control [min]	Waiting time in queue of buses, for custom control [min]	Waiting time in queue of truck, for custom control [min]
2	2	211.4	206.6	212.1	1.1	5.8	0.2
3	2	8.2	8.2	8.2	6	3.4	2.5
3	3	8.4	8.4	8.3	1.1	0.3	0.1
4	4	1.9	1.6	1.5	0.1	0.1	0

Using the same simulation model, the waiting time can be estimated for other types of actions or combination of them, for example, increasing time controls because of the additional caution for crime prevention and the compensatory increase in the control staff.

6. CONCLUSIONS AND FURTHER ANALYSIS

Transport and trade are influenced by the state of the transport infrastructure along the transnational long routes and also by the waiting time for the border crossing procedures, especially in border crossing points between the EU territory and neighbouring countries, when rigorous controls are required.

The EU project ACROSSEE presented the opportunity to highlight the difficulties in BCPs; it provided the analyses and proposals for the improvement of transit time, on short and medium time.

The mathematical model which describes the processes in BCP is the queue model, but future investigations are needed to find the appropriate regime of the operation (stationary or non-stationary regime, interrupted or non-interrupted service); the appropriate arrival and service distributions, including the accuracy of their parameter estimations; service priorities, if any; the dynamic resource allocation; occurrence of special events and the distribution of these events, etc.

The simulation modelling is a valuable instrument in case of the difficult and realistic mathematical modelling; the results of different types of the improvement actions or a combination of actions can be rigorously assessed in terms of waiting time in queue and total time in the system.

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