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MODEL FOR THE OPTIMIZATION OF TECHNOLOGY AND CAPACITY IN MARSHALLING STATION

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Abstract: *Marshalling stations are centers intended for large scale decoupling and composing of trains. They are placed at points of large scale loading and unloading, as well as at railway line connection or intersection points and major traffic nodes. Marshalling stations are centers where railway transport components spend considerable time in the process of the fulfillment of their demands. They perform a maneuvering operation, consisting of composing and recombining of the train components.*

According to their characteristics, marshalling stations can be considered complex technical - technological systems. They service trains that require the processing, decoupling, re-combining after the wagons are gathered, locomotive servicing and shipping. At each stage, the system is comprised of the three basic components: input, service and output, as well as frequent queues. These serve as guidelines in identifying the key Queuening model components.

This work presents the implementation of the technology modeling of railway station functioning aiming to the optimisation of technologycal processes and to the capacity dimensioning, which can affect the shortening of wagon delay time. Solving of this problem will inclide application of Queuing. In the paper, models of the admission park are developed, based on non – Markov Queuing model, using the example of the Novi Sad Marshalling Station.

Key words: *modeling, Queueing model, optimization, marshalling station*

I. INTRODUCTION

In the transport from the source to the destination station, vehicles (as well as transported goods) are retained in marshalling stations for shunting. Specialized railway stations that are equipped with facilities for the effective execution of the large-scale maneuvering tasks, as well as the decoupling and the formation of freight trains, are referred to as marshalling stations.

Marshalling stations are also points that can slow down the transport of goods, primarily due to the unavoidable wagon accumulation prior to processing. Inefficiency introduced by marshalling stations into transport of goods is also due to other activities the trains are subjected to or involved in. Such activities include train preparation for admission into the station, preparing for decoupling, the composition decoupling, monitoring the wagon accumulation process, preparation for shipment of accumulated freight, and train dispatch. Therefore, optimization process within the marshalling stations is of great importance for the more efficient transport of goods and reduction in overall transport costs, which can directly affect the rail transport competitiveness. In other words, the marshalling station optimization has a direct influence on supply chain efficiency, as it is a very important link.

Optimizing the use of railway infrastructure is a complex and difficult task. The capacities of one railway station, in specified time period and terms, are enabling receipt, processing and dispatch trains. Defining capacity is needed to define the time tables, the traffic organization and technological processes, their optimization, planning of investments etc. The basic problem which arises is how to dimension capacities, so the train service can be carried out without problems. Accordingly, it is necessary to have in mind that infrastructural facilities and resources are extraordinarily expensive at the building and procurement point as well as at the maintaining one. Also notable are the costs of labor.

This means that their improper dimensioning can affect the railway profitability because railway capacity is not static, and it is extremely dependent on the way of use.

In literature there are many methods and models for dimensioning of railway capacity.

The International Union of Railways (UIC), proposed the UIC method. It calculates capacity in line sections to identify bottlenecks. It takes into account the order of trains, and a buffer time is inserted to achieve an acceptable quality of service. This method was officially dropped some years ago and is no longer recognized as a standard. It has been superseded by more general recommendations that establish a link between railway capacity and railway quality [1]. In their last recommendation, the International Union of Railways presented the compaction method (UIC 406 method) as the best way of performing a capacity study. The capacity calculation is based on the compression of timetable graphs on a defined line or line section.

The paper [1] provides an overview on the main concepts and methods for capacity analyses, and presents an automated tool that is able to perform several capacity analyses. These analyses are related to certain determination of capacity of certain railroads sections but not for facilities of railway stations.

In the work [2] for traffic congestion controls a queue thresholds are used. For the queuing theory the system GE/GE/1/N approximation is used, developed to study the spread of traffic congestion in complex networks. Then, for modeling the spread of traffic congestion in complex rail networks in [3] a Weight-evolving traffic network model is used, which is based on Barrat–Barthelemy–Vespignani (BBV) model. This paper simulates and analyzes the process of the emergence and spreading of congestion, which is triggered by adjusting of data generating speed and data sending ability of the network.

The railway traffic management is presented in paper [4], in which new extended equation for train traffic and its impact on the length of the braking distance when several trains are in traffic, is presented. For this purpose, numerical and simulation analysis are performed.

The technology and railway station capacity modeling are presented in the following works: [5], [6], [7] and [4]. In the work [5] a simulation model for technology and capacities optimization for interim stations (transit stations) is presented, with usage of the Non-Markov systems queuing theory. To simulate the railway traffic at the stations (into the railway transit stations), in [4] Cellular Automata is used, and in the [6] hybrid Petri nets-based simulation model. In the work [7], marshaling yard station model is presented, where the station optimization is the main question, and is based on the simulation modeling of the technological operations such as train formation and unformation. The analytical modeling of the technological operations in the marshaling yards is made in the work [8].

The simulation modeling for other types of traffic is applied for investigating the dynamic behavior of the transfer process at the ports [9].

In general, the models for dimensioning of railway facilities can be: analytical, graphical, models which are using theory of probability and mathematical statistics, and models of applied Queuing Theory based on mathematical modeling of technological processes and computer simulation [7].

Analytical models for determining the capacities do not take into account technological processes and do not provide multivariate solutions. Accuracy of these models is much smaller in relation to others. Graphical models directly depend exclusively on the train schedules and standardized technological times duration of the activities and operations. These models are tested within each change of train schedule. The application of the Queuing Theory gives good results in the analysis and determination of stochastic systems. The main problem in applying this theory is the choice of best suited queuing system to solve the set of problems. A specific problem is determining the exact distribution of the input stream and the time of its serving.

Optimization methodologies used in practice tend to combine two or more basic techniques.

This paper presents the technology and capacity modeling of the marshalling station admission park based on the queuing theory.

II. TECHNOLOGY AND CAPACITY MODELLING OF THE MARSHALLING STATION ADMISSION PARK

Due to the complexity associated with modeling technology and capacity of the entire marshalling station, in this paper only the technological processes in the admission park are modeled (AP). These technological processes result in a less dependent technological unit [5] [10]. In this paper, two models of the admission park are developed, based on non-Markov Queueing model, using the example of the Novi Sad marshalling station.

A. *Non-Markov Queueing Model $M/E_k/1/\infty$*

The timetable is governed by the train input flow into the marshalling station. Based on the timetable analysis using the historical data, in the Novi Sad marshaling station, on average, treatment (decoupling) of 20 freight trains was planned.

The technological process is based on two maneuvering units operating within the admission park. Under such an arrangement, one unit is working on processing compositions in the admission park, whereas the other conducts the same operations in the transit station. At the marshalling station Novi Sad, there are two shunting locomotives, one of which is used for train decoupling, and the other for supplying wagons to the sidings.

Based on the train traffic chart analysis, the key parameters of the intervals between train arrivals into the marshalling station are determined (Table I).

TABLE I. TRAIN INPUT STREAM AND PROCESSING PARAMETERS IN THE MARSHALLING STATION NOVI SAD AP

Distribution parameters	**The arrival of trains**		**Operation of trains**	
	Sign	*Value*	*Sign*	*Value*
Expected value	$M(I)$	61.85 min	$M(t_{op})$	26.55 min
Intensity	λ	0.97 trains/h	μ	2.26 trains/h
Dispersion	$D(I)$	4579.88 min^2	$D(t_{op})$	173.25 min^2
Standard deviation	$\sigma(I)$	67.675 min	$\sigma(t_{op})$	13.16 min
Coefficient of variation	v_{ul}	1.094	v_{op}	0.5
The shape parameter	k_{ul}	0.83	k_{op}	4.06
The degree of occupancy of the system	ψ	0.43		

For the calculation of parameters, the theoretical exponential distribution for the arrival at the station of trains to be serviced is assumed. Based on the χ^2 test, a theoretical hypothesis is postulated and subsequently verified.

Based on the analysis of the station technological process, the AP servicing time parameters were determined (Table I). Using the calculated parameters, composition processing in the admission park is described using the Erlang theoretical distribution of the fourth order. The χ^2 test verified the original theoretical hypothesis.

The above established composition processing time distribution law is also discussed in the paper [10]. In these studies, it was determined that for marshalling stations on the Serbian railways, the processing time followed the Normal or Erlang distribution, and less frequently exponential distribution.

Based on the transit train traffic chart analysis, the key parameters of the intervals between train arrivals into the marshalling station are determined (Table II).

TABLE II. TRAIN INPUT STREAM AND PROCESSING PARAMETERS FOR TRANSIT TRAINS

Distribution parameters	**The arrival of trains**		**Operation of trains**	
	Sign	*Value*	*Sign*	*Value*
Expected value	$M(I)$	52.59 min	$M(t_{op})$	12 min
Intensity	λ	1.14 trains/h	μ	5 trains/h

Dispersion	$D(I)$	5477.74 min^2	$D(t_{op})$	1.33 min^2
Standard deviation	$\sigma(I)$	74.012 min	$\sigma(t_{op})$	1.15 min
Coefficient of variation	v_{ul}	1.4072	v_{op}	0.1
The degree of occupancy of the system	ψ	0.228		

In this paper, the following Queueing model was applied: Poisson input stream – Erlang time servicing ($M/E_k/1/\infty$) in order to test technologies transit trains of the previous operations in the AP. By introducing constraints on the train processing activities in the AP, the model is treated as a Single-server Queueing model.

The average number of customers in the queue (for the trains on which decoupling is performed), i.e. those awaiting the service is given by:

$$(1)\quad \bar{k}_r = M(n_{\check{c}}) = \frac{\psi \cdot (k+1)}{2 \cdot k \cdot (1-\psi)} = 0.47$$

where k is the Erlang distribution serving time parameter.

Average waiting time:

$$(2)\quad \frac{k+1)}{\cdot(2-\psi)} = 0.0757\,(h) = 4.54\ (\text{min})$$

Average number of clients in the system is given by:

$$(3)\qquad \bar{k} = M(n_s) = \frac{\psi \cdot (k+1)}{2 \cdot k \cdot (1-\psi)} + \frac{\psi \cdot (k-1)}{2 \cdot k} = 0.63$$

Dispersion of the number of clients in the system:

$$(4)\quad D(n_s) = \frac{\psi \cdot (k+1)}{12 \cdot k^2 \cdot (1-\psi)^2} \cdot \left[2 + 4 \cdot k + \psi \cdot (1-k)\right] = 0.3$$

The last step in this cycle is the calculation of the objective function, which consists in minimizing the total annual cost of the AP operation, comprised of the costs of keeping the wagons in the queue due to waiting on the completion of the preceding operations, performing the previous operations, as well as labor costs associated with performing the operations. Operational costs in the AP can be determined by applying (5).

$$(5)\quad \begin{aligned} E &= 365 \cdot N_r \cdot m \cdot C_{k\check{c}} \cdot (t_{zd} + t_{\check{c}}^{ob}) + \\ &+ 12 \cdot \left[4.5 \cdot (xC_{kp} + yC_{tp} + zC_{pm})\right] = 113251.05\ € \end{aligned}$$

where:

m - average number of wagons in the train;

t_{zd}– occupancy time of a single-track composition, based on the technological process of AP operation in hours;

$C_{k\check{c}}$– cost of wagon hours 0.77€/h;

C_{kp} - monthly cost of the party in a commercial review 440.95 €;

C_{tp} - monthly cost of the party in the final technical inspection of 403.225 €;

C_{pm} - monthly cost of the party in the preparation for maneuvering the composition 334.97 €.

In this paper, the following Queueing model was applied: Poisson input stream - Normal distribution of servicing time ($M/D/1/\infty$) in order to test technologies transit trains of the previous operations in the AP.

The average number of customers in the queue (transit trains), i.e. those awaiting the service is given by:

$$(6)\quad M(n_{\check{c}}) = \frac{\psi^2}{2 \cdot (1-\psi)} = 0.034$$

Average waiting time:

$$(7)\quad t_{\check{c}} = \frac{\psi^2}{2 \cdot \lambda \cdot (1-\psi)} = 0.03\,(h) = 1.8\ (\text{min})$$

Average number of clients in the system is given by:

(8) $$\bar{k} = M(n_s) = \frac{\psi}{2 \cdot (1-\psi)} = 0.15$$

Average time to keep clients in the system:

(9) $$\bar{t}_s = \frac{\psi}{2 \cdot \lambda \cdot (1-\psi)} = 0.13h = 7.8(\min)$$

The last step in this cycle is the calculation of the objective function, which consists in minimizing the total annual cost of the AP operation by applying (10).

(10) $$E = 365 \cdot N_t \cdot m \cdot C_{k\check{c}} \cdot (t_{zd} + t_{\check{c}}^{ob}) + 12 \cdot 4.5 \cdot p \cdot C_t = 47953.96 \text{ €}$$

where:

p – number of workers.

B. Marshalling station as a network of Queueing models – System 1 and 2

Queueing model network of a non-gravitational station with parallel admission park position, as is the case of the marshalling station Novi Sad, comprises 6 or 7 systems [10]:

- System 1 - "admission park, input sections",
- System 2 - "admission park, decoupling",
- System 3 - "marshalling-output park, re-coupling",
- System 4 - "finishing operations in the marshalling-output park",
- System 5 - "servicing the shunting locomotives in the marshalling-output and transit park",
- System 6 and 7 - "marshalling-output park, output sections".

Based on the technological connection between System 1 and 2, it follows that the output flow of System 1 is the input to System 2. The intensity of the input stream is (λ):

(11) $$\lambda = \frac{N_r}{24} = 0.83 \ \ (trains / h)$$

where:

N_r - average number of the decoupled trains in one day;

The first step determines the duration of the composition treatment, by individual operations in System 1. This requires determination of the minimum number of parties performing each function. It was established that one member of staff is required to perform each of the following: commercial examination (x), the final technical inspection (y) and the preparation of the composition for the maneuver (z).

The model is further based on the principle of changing the number of parties (x, y and z), from the minimum upwards, until the optimal solution is found.

The next step is to establish, for specific conditions (based on the technological process), the duration of appropriate activities and to define the activity on the critical path, i.e. the activity of the maximum duration:

(12) $$t_{ob} = t_{ob}^{kr} = \max \left\{ t_{ob}^{kp},\ t_{ob}^{tp},\ t_{ob}^{pm} \right\}$$

For processing operations in the AP of the marshalling station Novi Sad, it was shown that the preparation of the composition for the maneuver was the activity on the critical path, corresponding to the duration of 0.5 h (30 min).

In order to determine the queuing time prior to processing, first, it is necessary to determine, in relation to the critical activity, the following:

- Party occupancy coefficient on the critical path (ψ_{pr}^{kr}):

(13) $$\psi_{pr}^{kr} = \psi_{pr} = \frac{N_r \cdot t_{ob}}{24} \cdot \left(1 + \frac{T_{pr}^{kr}}{24 - T_{pr}^{kr}}\right) = 0.45$$

where T_{pr}^{kr} is the length of latent period in the operation (2 h).

- Processing time coefficient of variation (ν_{ob}) which is equal to the processing time coefficient of variation on the critical path (ν_{ob}^{kr}) for marshalling station input flows, and can range from 0.2 to 0.35 [10]. In this study the value of $\nu_{ob} = \nu_{ob}^{kr} = 0.3$ was adopted.

Queuing time prior to processing is calculated applying (14).

(14) $$t_{\check{c}}^{ob} = \frac{\psi_{pr} \cdot (1+\nu_{ob}^2)}{2\cdot(1-\psi_{pr})} \cdot t_{ob} = 0.22\ (h)$$

The next step is to determine the number and the dispersion of the number of compositions that are waiting for completion of preceding operations:

- Expected value of the number of compositions in the queue, as given by:

(15) $$M(n_{\check{c}}^{ob}) = \frac{N_r}{24} \cdot t_{\check{c}}^{ob} = 0.18(h)$$

- Dispersion of the number of the compositions in the queue, as given by:

(16) $$D(n_{\check{c}}^{ob}) = \left[M(n_{\check{c}}^{ob})\right]^2 + M(n_{\check{c}}^{ob}) = 0.21$$

By applying (5), the goal function for this model is obtained and is given by E_1^g *=124380.63 €.*

The values derived for System 1 are used as input parameters in the calculation of the System 2 determinants, adopting the following values:

- Number of parties *x, y,* and *z*,
- Composition processing duration on the critical path t_{ob},
- Processing time coefficient of variation ν_{ob}.

System 1 output flow coefficient of variation, which is also the input to System 2 (for the decoupling trains), is given by [10]:

(17) $$\nu_{\text{izl}} = \sqrt{1-\psi_{\text{pr}}^2 \cdot (1-\nu_{ob}^2)} = 0.9$$

Decoupling system occupancy is given by:

(18) $$\psi_i = \frac{N_r \cdot t_i^i}{1440} = 0.28$$

Average composition waiting time prior to decoupling is:

(19) $$t_{\check{c}}^i = \frac{\psi_i \cdot \left(\nu_{iz}^2 + \nu_{ob}^2\right)}{2\cdot\left(1-\psi_i\right)} \cdot t_i^i = 3.5(\text{min}) = 0.058\ (h)$$

Average number of compositions waiting for the decoupling in the AP is:

(20) $$M(n_{\check{c}}^{rf}) = \lambda \cdot t_{\check{c}}^i = 0.048$$

Dispersion of this number of compositions is:

(21) $$D(n_{\check{c}}^b) = \left[M(n_{\check{c}}^{rf})\right]^2 + M(n_{\check{c}}^{rf}) = 0.05$$

where:

M_{ml}^i - number of shunting locomotives;

t_i^i - average technological interval; value for the decoupling system is 20 min.

Based on the technological connection between System 1 and 2, it follows that the output flow of System 1 is the input to System 2. For transit trains, the intensity of the input stream is (λ):

(22) $$\lambda = \frac{N_r}{24} = 0.125\ \ (trains/h)$$

where:

N_r - average number of the decoupled trains in one day;

The first step determines the duration of the composition treatment, by individual operations in System 1. This requires determination of the minimum number of parties performing on technical examination (p). For existing situation in marshaling station Novi Sad, number of workers in the processing of transit trains is 1.

The next step is to establish, for specific conditions (based on the technological process), the duration of appropriate activities and to define the activity on the critical path, i.e. the activity of the maximum duration:

(23) $$t_{ob} = t_{ob}^{kr} = 0.2(h)$$

- Party occupancy coefficient on the critical path (ψ_{pr}^{kr}):

$$(24)\qquad \psi_{pr}^{kr} = \psi_{pr} = \frac{N_r \cdot t_{ob}}{24} \cdot \left(1 + \frac{T_{pr}^{kr}}{24 - T_{pr}^{kr}}\right) = 0.25$$

Queuing time prior to processing is calculated applying (8).

$$(25)\qquad t_{\check{c}}^{ob} = \frac{\psi_{pr} \cdot (1 + v_{ob}^2)}{2 \cdot (1 - \psi_{pr})} \cdot t_{ob} = 0.036\,(h) = 2.18(\min$$

- Expected value of the number of compositions in the queue, as given by:

$$(26)\qquad M(n_{\check{c}}^{ob}) = \frac{N_r}{24} \cdot t_{\check{c}}^{ob} = 0.04(h)$$

- Dispersion of the number of the compositions in the queue, as given by:

$$(27)\qquad D(n_{\check{c}}^{ob}) = \left[M(n_{\check{c}}^{ob})\right]^2 + M(n_{\check{c}}^{ob}) = 0.042(h)$$

By applying (10), the goal function for this model is obtained and is given by $E_{1t}^{g} = 48636.91$€. Total cost of System 1 for the decoupling trains and for transit trains with the existing organization of work: $E = E_1^g + E_{1t}^g = 173017.54$€.

To determine the optimal mode of operation in the AP, taking into account the cost of wagon processing and retention, it is necessary to examine several variants of engagement of staff in the composition processing (*x, y, z, p*), based on the condition that a single shunting locomotive is conducting preceding operations. Employing a second shunting locomotive in performing preceding operations would not be feasible at the station Novi Sad, due to the technology involved in simultaneous operation of two locomotives and a number of intersections within the existing rail track system.

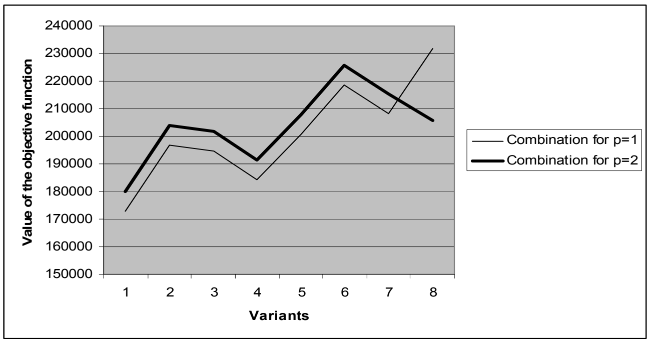
By changing the number of parties engaged in the process (*x, y, z, p*), System 1 determinants can be calculated, and for each variant, the function *E* is determined.

In the present work, eight variants were tested (Table III).

TABLE III. AP PROCESS ORGANIZATION COSTS FOR EACH VARIANT

Variant	*x*	*y*	*z*	*p*		$E_1^g + E_{1t}^g$ *(for p=1)* *(€)*	$E_2^g + E_{2t}^g$ *(for p=2)* *(€)*
I	1	1	1	1	2	**173017.54**	180153.76
II	2	1	1	1	2	196828.84	203965.06
III	1	2	1	1	2	194791.69	201927.91
IV	1	1	2	1	2	184360.72	191496.94
V	1	2	2	1	2	200738.71	207874.93
VI	2	2	1	1	2	218602.99	225739.21
VII	2	1	2	1	2	208172.02	215308.24
VIII	2	2	2	1	2	231632.47	205768.69

Minimal organizational costs are identified for Variant I. The Results of the composition processing cost of the previous operations in combination p = 1 and p = 2 are shown in the following graphic.



GRAPH I. **Cost of flies on the composition of the previous operations**

The above analysis shows that, within the total operational cost of System 1 and 2, the defined composition processing technology in the marshalling station Novi Sad is optimal. However, this conclusion may be affected by the analysis of the entire operational technology of the observed marshalling station (in the present work, only System 1 and 2 are analyzed). Nonetheless, given that extant empirical evidence suggests that the effects of the remaining marshalling station systems (Systems 3 ÷ 10) do not significantly affect the operation of System 1 and 2, they can be considered and analyzed as a single, independent marshalling station segment [5] [10]. This is due to the fact that, after the composition decoupling in System 2, trains—as integral units—cease to exist. The total wagon retention time in AP conditions [10]:

- System 1 and 2 optimal performance:

(28) $t_{pp} = t_{\check{c}}^{ob} + t_{zd} + t_{\check{c}}^{i} + t_{rs} - t_1 = 59.5\,(\text{min}) = 0.99\,(h)$

- Track occupancy time due to AP activities:

(29) $t_{zk} = t_{fp} + t_{ui} + t_{zd} + t_{rs} - t_1 = 52\,(\text{min}) = 0.87\,(h)$

where:

t_{fp} - time required to identify and plan the route (5 min);
t_{ui} - the time of entry into the train station (4 min);
t_1 - coupling dismantling time (7 min).

Number of tracks in AP:

(30) $$K_{pp} = \frac{N_r \cdot t_{zk}}{24} + M(n_{\check{c}}^{ob}) + M(n_{\check{c}}^{rf}) + 1{,}5 \cdot \sqrt{D(n_{\check{c}}^{ob}) + D(n_{\check{c}}^{rf})} = 1{,}72\,(tracks)$$

where $K_{pp}=2$ *(tracks)* is adopted.

III. MODEL RESULTS ANALYSIS

Even though there are some differences in the input flow and queue intensity, the results have shown that the degree of system occupancy in both models is approximately the same (Table IV). These findings suggest that the station could accommodate more trains to be processed with existing staff and rail track facilities. Even the annual composition processing costs of the preceding operations did not differ significantly.

TABLE IV. COMPARATIVE REPRESENATION OF MODEL RESULTS

Parameters of system	$M/E_K/1/\infty$	System 1
λ- intensity of the input stream (*trains/h*)	0.97	0.83
μ- intensity of servicing (h^{-1})	2.26	2
$\bar{k}_r$ - average number of compositions waiting	0.47	0.18
$t_{\check{c}}$ - average waiting time (*min*)	4.54	13.2
ψ- the degree of occupancy of the system	0.43	0.45
E - Operational costs in the AP (*€*)	113251.05	124380.63

The slight discrepancy was found only in the duration of waiting for the commencement of treatment (4.54 min and 13.2 min) and average number of customers in the queue (0.47 and 0.18). However, the value of these parameters is very small.In this paper, the application of Queueing theory has shown that, with respect to a defined composition treatment technology, for the given timetable, there are gaps in terms of utilization of staff and the station capacity.

According to the train timetable, most compositions arrive for treatment in the marshalling station Novi Sad in the period from 17:41h to 19:19h (period of peak demand). The existence of this peak period is the cause of queues forming before the start of treatment. Thus, in order to reduce waiting times as well as the corresponding costs, more workers could be utilized in the period of peak demand, if necessary. Further improvements can be achieved by better timetable organization, i.e. by distributing the train arrivals to the marshalling station more evenly.

IV. CONCLUSION

In the process of distribution, from the place of production to that of consumption of goods, significant time is spent in marshalling stations. The marshalling stations are crucial components of the supply chain, especially when it comes to un-streamlined and unpackaged flow of goods transported by rail. Therefore, in terms of distribution time and costs, it is crucial to optimize the work in marshalling stations.

The paper presents the marshalling station AP technology and capacity modeling by applying Queueing theory to optimize the AP operations. The models were tested on the example of the marshalling station Novi Sad, located on Corridor X.

To define the optimal marshalling station operation mode in the AP, two models were defined: non-Markov Queueing models (model $M/E_k/1/\infty$), whereby the compositions are processed (decoupled), and the model that describes the marshalling station as a network of Queueing models.

Both models have shown that the defined AP technology and capacity in the marshalling station meet the predetermined schedule. Moreover, there are additional opportunities to better utilize the staff and capacity.

In order to reduce retention times for the compositions being processed, it is necessary to analyze the potential of modernizing the operations by using bar code readers and RFID (Radio Frequency Identification) technology. Such improvements could yield reduction in operating costs. However, significant research should be conducted in order to reduce the composition queuing times that currently exist between Systems 2 and 3.

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МОДЕЛ ЗА ОПТИМИЗИРАНЕ НА ТЕХНОЛОГИИТЕ И КАПАЦИТЕТА В РАЗПРЕДЕЛИТЕЛНА ГАРА

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***Ключови думи**: моделиране, модел на опашките, оптимизация, разпределителна станция*

***Резюме**: Разпределителните гари са центрове, предназначени за разкомпозиране и композиране на влакове в голям мащаб. Те са поставени в точки на широкомащабно товарене и разтоварване, както при свързване на железопътните линии или пресечни точки и основни пътни възли. Разпределителните гари са центрове, където компонентите на железопътния транспорт прекарват значително време в процеса на изпълнение на свето предназначение. Те извършват маневрени операции, състоящи се от композиране и рекомпозиране на компонентите на влака.*

Според своите характеристики, разпределителните гари могат да се смятат за сложни технико- технологични системи. Те обслужват влакове, които изискват обработка, декомпозиране, рекомпозиране след вагоните, обслужване с локомотиви и изпращане. На всеки етап системата се състои от три основни компонента: вход, услуги и изход, както и чести опашки. Те служат като насоки при идентифицирането на ключовите компоненти на модела ня опашките.

Тази доклад представя изпълнението на технологично моделиране на функционирането на железопътна гара с цел оптимизиране на технологичните процеси и оразмеряване на капацитета, което може да въздейства за съкращаване на времето за закъснение на вагоните. Решаването на този проблем включва прилагане на модела за опашките. В статията са разработени модели за пропускателен парк въз основа на не-Марков модел за опашките, Като се използва примерът на разпределителната гара в Нови Сад.