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RIPPLE EFFECTS IN YARD OPERATIONS

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Abstract: *Ripple effects are encountered when the system under study is characterised with non-stationary arrivals. The rail freight yards are typical examples for such phenomena. They are facilities that deal with non-stationary arrivals, meaning over a certain period of time there are intervals of intensive arrivals of freight trains followed by lulls. Thus, the customers, which in our case are the incoming freight trains, are served in spurts. The ripple effect tends to quickly oversaturate the yard, especially when the scheduled freight trains to arrive are very close to or even above the yard processing capacity limits. Therefore, an additional care should be paid when one deals with non-stationary arrival processes, explicitly considering the fact that such systems pass through different state phases.*

In this paper, we investigate a yard performance that appears to suffer a ripple effect. In order to study this phenomenon a simulation event-based model has been developed and implemented in terms of a flat-shunted rail freight yard.

Key words: *Rail Freight Transportation, Rail Yards, Freight Trains, Arrival Process, Ripple Effect*

CASE STUDY

OBJECT OF STUDY

In this paper, in the shape of “Case Study”, we investigate a yard performance that appears to suffer a ripple effect. In order to study this phenomenon a simulation event-based model has been developed using SIMUL 8 and implemented in terms of “Pampilhosa” flat-shunted rail freight yard. For the yard modelling purposes, the decomposition approach is employed [1], [2], [3], [4], [5], [6] and [7], meaning the yard under study is decomposed into areas, such as: Arrival Yard, Shunting Zone, Departure Yard, etc. In each area, different successive operating processes with freight trains are executed by the yard crew. Generally speaking, each operating process is defined by both an arrival pattern and a service pattern. On the other hand, the yard crew responsible for the execution of the yard operations consists of *Classification Man*, *Shunting Crew* and *Inspection Man*, and in our study we are able to observe their utilization rates under different conditions and scenarios as well as other measures of performance (MOP), as we will see later on in this paper.

YARD DESCRIPTION

The rail freight facility “Pampilhosa” functions as a classification/formation yard and serves Linha da Beira Alta, partly Linha do Norte and Linha do Oeste as well as Ramal da Figueira da Foz from the Portuguese rail network. Pampilhosa layout is shown on Figure 1, below. Tracks I-N; II-N; I-B and II-B are used for passenger service, i.e., these are the main lines of passenger station of “Pampilhosa”. These tracks are not used for shunting purposes.

Track number IV-N is not electrified and is usually used for receiving and leaving freight trains equipped with diesel traction. Tracks III N, III - B and IV B are electrified and are used for receiving and leaving freight trains equipped with both diesel and electrical traction. Thus tracks IV-N, III N, III - B and IV B specify both the arrival yard and the departure yard of "Pampilhosa". The shunting zone (SZ) is generally concentrated on tracks IV-B, V-B, VI-B and VII-B. The pieces of tracks XVI, XVII and XVIII are not electrified and they are usually used for storing diesel road locomotives. The electrical road locomotives are usually stored on track VIII-B. Tracks IX-B; X-B and XII-B are not electrified and are usually used for storing freight cars not in current use as well as shunting. There is only one shunting crew in operation at the time.

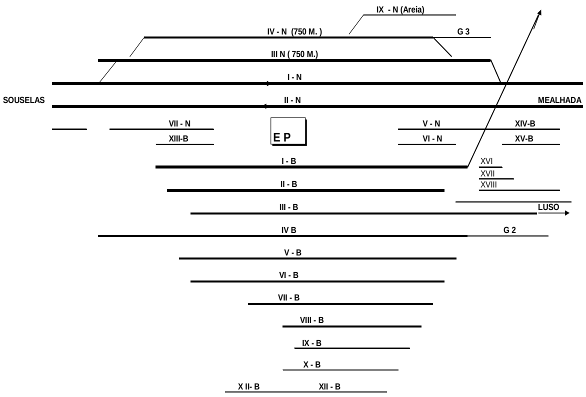


Figure 1 Layout of Yard "Pampilhosa"
<u>Source:</u> Department of Planning and Control at CP Carga

EXPERIMENT

According to the current schedule of CP Carga (the rail freight operator under study), the daily freight trains' arrivals at Pampilhosa yard are subordinated to the pattern given in Table 1. This is the time – dependent distribution that is set up in our simulation model. Note that there are regular periods of time in which no freight train arrivals are expected. Normally, the analytical models are not capable of capturing such a particularity. In fact, analytical approaches that may be of interest here are those that deal with non-stationary arrivals. It is said that a given system is in Quasi-steady state if the arrival rate is slowly and constantly varying, and the system in question operates below its capacity. Then, steady-state equations can be used to approximate the behaviour of such a system. If the steady-state equations, however, do not provide plausible results, meaning this approach is not applicable to the particular case, one ends up with simulation. In either case, this subject might be of interest for further research in terms of yard operating processes and railway freight operations as a whole.

Time Dependent Distribution	
Periods	Freight Train Arrivals
From 0:00 to 1:00	0
From 1:00 to 4:00	5
From 4:00 to 6:00	5
From 6:00 to 9:00	0
From 9:00 to 12:00	5
From 12:00 to 15:00	4
From 15:00 to 18:00	0
From 18:00 to 20:00	4
From 20:00 to 24:00	5

Table 1 Time-Dependent Freight Train Arrivals, Pampilhosa Experience
<u>Source:</u> Department of Planning and Control at CP Carga

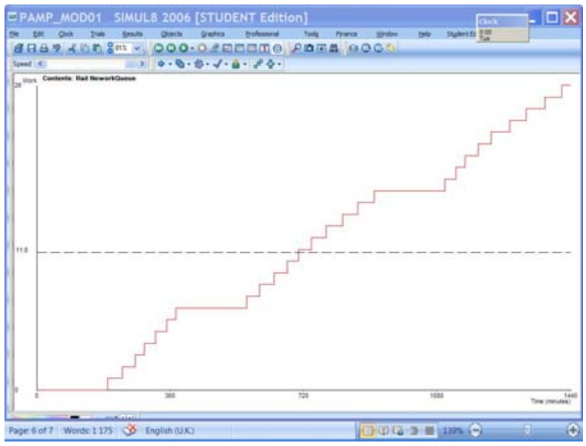


Chart 1 Time Dependent Distribution of Scheduled Arrivals of Freight Trains at Pampilhosa

Coming back to yard experiment, Chart 1 visualizes well the scheduled freight train arrivals at Pampilhosa over the regular daily cycle. It appears that this yard suffers a *ripple effect*. The first special feature is that the current arrival pattern causes the freight trains to be served in spurts by Pampilhosa and the second special feature is that there are regular periods of time in which the intensive freight train arrivals are followed by evident lulls. This phenomenon can also be seen in the technological yard subsystem performance. Similarly, dictated by the arrival process of freight trains the yard subsystems are busy over regular periods of time of intensive arrivals followed by periods of being idle, where no freight train arrivals occur. In order to show this a directly produced chart by SIMUL 8 is given. This is Chart 2 showing the service patterns of three Pampilhosa subsystems dedicated to "*Commercial and Technical Inspections*" in the arrival yard, "*Breaking Down"* and "*Making Up*" of freight trains in the shunting zone. Note that in all three subsystems the service patterns are nearly the same.

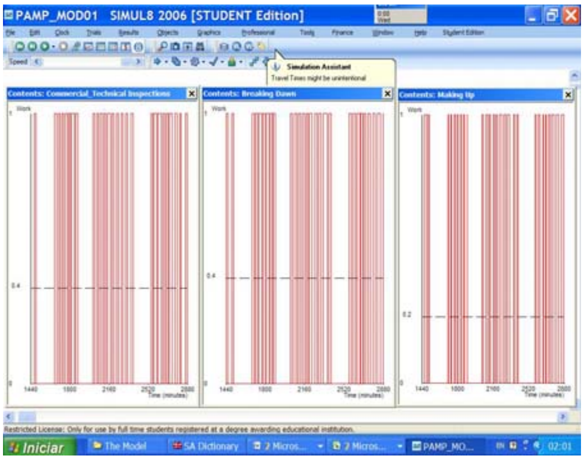


Chart 2 Service Patterns of Yard Subsystems due to Non-stationary Arrivals of Freight Trains, Pampilhosa Experience

The ripple effect tends to quickly over-saturate the yard, especially when the scheduled freight trains to arrive are very close to or above the yard capacity limits seen in the yard physical possibilities to accommodate incoming freight trains. Therefore, an additional care should be taken when one is dealing with non-stationary arrival processes because the systems under study pass through different state phases, as evidenced by the service patterns shown in Chart 2.

After having conducted a 1000 runs' trial based on the inputs given in Table 1 and Chart 1, plausible results have been obtained demonstrating that most of the yard subsystems show relatively high percentage of being awaiting work. It is not surprising, bearing in mind that there are few tracks on which a set of consecutive operations is fulfilled. What is also of interest is that some of Pampilhosa subsystems demonstrated a percentage of time in which they were being blocked. This percentage is expected to be on the increase in case of further increases in the freight trains to be processed by Pampilhosa. Another measure that deserves attention obtained by our model is the estimated level of shunting crew utilization rate, which comes up to 63 percent in this trial. This is a relatively high value, which further indicates that Pampilhosa may not handle much more increases in the freight train arrivals, however.

Nevertheless, we look at changes in the number of arrivals of freight trains at Pampilhosa, i.e., traffic rules. In order to further examine this phenomenon we conducted five different trials. In all but the fifth trial, the arrival process is non-stationary. In the fifth trial the arrival process is stationary. The arrival patterns of the five trials are given in Table 2. For the sake of simplicity, the first four trials are named by their sequential number (n-th pattern) and the fifth by "Stationary Arrivals".

Time Dependent Distributions – 5 Trials					
Periods	1st	2nd	3rd	4th	Stationary Arrivals
From 0:00 to 1:00	0	0	0	1	33 arrivals per 24 hours
From 1:00 to 4:00	5	5	5	5	
From 4:00 to 6:00	5	5	5	5	
From 6:00 to 9:00	0	0	1	1	
From 9:00 to 12:00	5	5	5	5	
From 12:00 to 15:00	4	5	5	5	
From 15:00 to 18:00	0	0	1	1	
From 18:00 to 20:00	4	5	5	5	
From 20:00 to 24:00	5	5	5	5	

Table 2 Arrival Patterns for Five Trials

Note that the difference between the trials is seen in the number of freight trains to arrive and the time at which the trains arrive. For the trials with non-stationary patterns, the basis is the first trial as Second Pattern, Third Pattern and Fourth Pattern are derived from First Pattern. Needless to say, the trial with stationary arrivals differs from the trials with non-stationary arrivals. However, this trial employs the same number of freight train arrivals as Fourth Pattern does and the emphasis here is on the fact that the results obtained from these two trials do not coincide.

In general terms, the results obtained are as follows: the Average Time in Yard as a whole system estimated by the trial with Stationary Arrivals is the lowest in comparison with all the other simulation trials. Also, it appears that in the stationary simulation trial, the percentage of time in which the Pampilhosa yard subsystems were being blocked has a tendency to be the lowest. Consequently, stationary arrivals appear to have a positive effect in terms of yards seen in both prevention of oversaturation of yard subsystems and reduction of average throughput time per freight train. Next, appears that the stationary arrivals contribute to small queue lengths and hence short queueing times. This phenomenon is examined in Chart 3 where the results of Time in Shunting Zone Queue for the five trials are depicted. Although the number of freight trains' arrivals is the same, the difference between Fourth Pattern estimate and Stationary Arrivals estimate is very visible indeed.

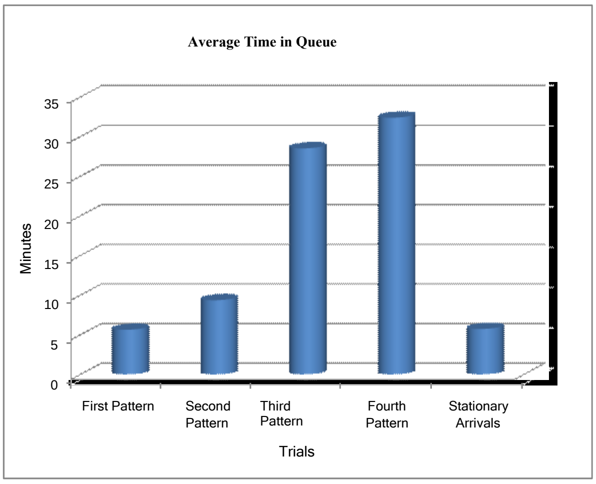


Chart 3 Times in Shunting Zone Queue, Comparison of Results for Five Simulation Trials, Pampilhosa Experience

Next, Chart 4 below visualizes the estimates of utilization rates of Classification man, Shunting crew as well as Inspection man. In all five trials the lowest utilization rate belongs to Classification man and the highest rate belongs to Shunting crew. It suggests that the labour category of classification man might be rethought in aid of inspection man, for instance.

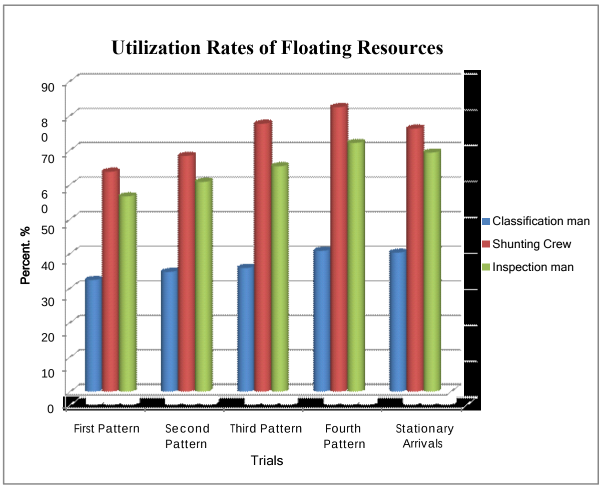
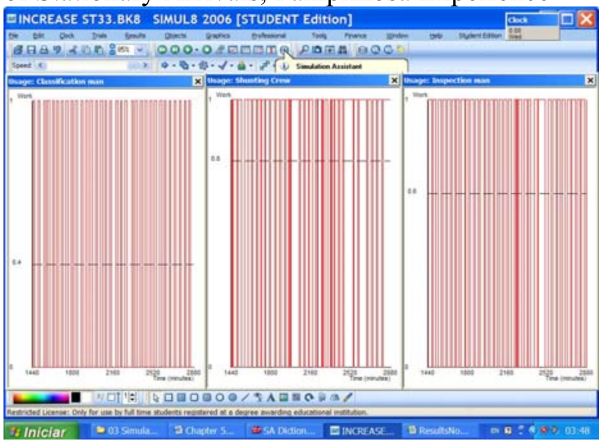


Chart 4 Estimated Utilization Rates of Pampilhosa Floating Resources for Five Trials

By comparison between the Fourth Pattern and the Stationary Pattern in terms of utilization levels of Pampilhosa floating resources, we have encountered that the estimates (i.e., measures of performance seen in queues behaviour and average serving times) obtained by the Fourth Pattern are higher than those obtained by the Pattern with Stationary Arrivals. It indicates that non-stationary freight train arrivals also require more effort to be made by the yard floating resources (especially the shunting crew as well as the inspection man) than stationary freight train arrivals do, when serving the same number of freight trains. This accumulates additional working costs, which ought to be avoided to the extent possible through better planning.

Chart 5 Behaviour of Floating Resources, Trial of Stationary Arrivals, Pampilhosa Experience



In Chart 5 above, the occupied times of Pampilhosa floating resources in the Stationary Pattern trial are intended to be visualized (from left to right: Classification man, Shunting crew and Inspection man). The Classification man's behaviour is described graphically by equal alternate pieces, where there is one closed piece replicating that the employee has worked followed by one empty piece replicating the employee has not worked. This phenomenon has not occurred in the behaviour of the other two resources. The alternate pieces describing shunting crew and inspection man's occupations in serving freight trains are much more fused. This exposes the high utilization rates of both the shunting crew and the inspection man, and further indicates that at the point of 33 freight trains to be served by Pampilhosa, the yard is already on the bound of its maximum processing capability.

SYNTHESIS

A simulation modelling experiment in terms of Pampilhosa flat-shunted rail freight yard has been conducted using event-based simulation software. In the early stage of this simulation experiment we discerned that Pampilhosa yard suffers a ripple effect. This phenomenon is characterized with repetitive periods in which no freight trains occur followed by periods of rush arrivals. The effect of ripple arrivals on the yard is seen in yard subsystems being busy over the periods of rush arrivals and yard subsystems being idle during the lulls. Non-stationary arrival processes cause the system to pass through different state phases. To further examine this phenomenon we conduct a Non-stationary vs. Stationary Experiment in terms of Pampilhosa. A number of simulation trials have been run. The positive effect of Stationary Arrival Patterns on yard performances has been seen throughout the conducted simulation experiment.

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ЕФЕКТ НА ПРОМЕНЛИВОСТ В РАБОТАТА НА РАЗПРЕДЕЛИТЕЛНИТЕ ГАРИ

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Резюме: *Ефектите на променливост се срещат, когато изследваната система се характеризира с непостоянните пристигания. Железопътните разпределителни гари са типични примери за това явление. Те са средства, които се прилагат при непостоянните пристигания, което означава, че през определен период от време има интервали на интензивно пристигане на товарни влакове, следвани от затишие. Така клиентите, които в нашия случай са идващите товарни влакове, се обслужват с голямо напрежение. Ефектът на променливост е насочен към бързо свръх запълване на разпределителната гара, особено когато товарните влаков, планирани да пристигнат са близо до или над границите на капацитета за обработване на гарата. Следователно трябва да се отделя допълнително внимание, когато се занимаваме с непостоянни процеси на пристигане, ясно отнасящи се до факта, че такива системи преминават през различни фази на състояние.*

В този доклад се изследва работата на разпределителна гара, която е засегната от ефекта на променливост. За да се изследва това явление, е разработен симулационен модел, базиран на събитията, който е приложен в условията на хоризонтално маневрена разпределителна сточна гара.

Ключови думи: железопътни товарни превози, разпределителни гари, товарни влакове, процес на пристигане, ефект на променливост.