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A SIMULATION MODELLING METHODOLOGY FOR ANALYZING YARD OPERATIONS

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Abstract: *A visual simulation model created and implemented using a computer package for event simulation, SIMUL 8 is provided. The main idea behind the simulation modelling approaches is to simulate the yard operation dividing the yard into segments so that the behaviour of each segment can be described and analyzed separately. The simulation model takes the shape of queuing network. The components of the queuing network are interconnected queuing systems that interact and influence one another, so that the global impact of freight train operations is captured. The queuing systems replicate the preliminary specified segments that consist of set of work centres (i.e., servers) and/or storage areas (i.e., capacity limitations). This modelling approach allows us to study the processing capabilities of the yards.*

Key words: *Railway Freight Transport, Yard, Simulation*

INTRODUCTION

Railway yards play a very important role in providing the railway freight transportation service. These facilities reassemble inbound freight trains into outbound freight trains and also service as storage areas in the railway network. In order to deal with random fluctuations and traffic imbalances the yards should ensure a desirable (large enough) buffer size that would further guarantee "*the yards do not congest the railway network*".

The yards are difficult for description and analysis. Within their limits a set of processes with freight trains are fulfilled. One possible method for studying yard operations is by modelling the yard operation with queueing models said to operate in steady state [4], [6]. However, analytical queueing models do not deal with variations and non-stationary arrivals. Such factors are typical for the freight transportation by rail. Moreover, analytical queueing models are not capable of capturing the global impact between the elements performing in a network and thus underestimate the system performances.

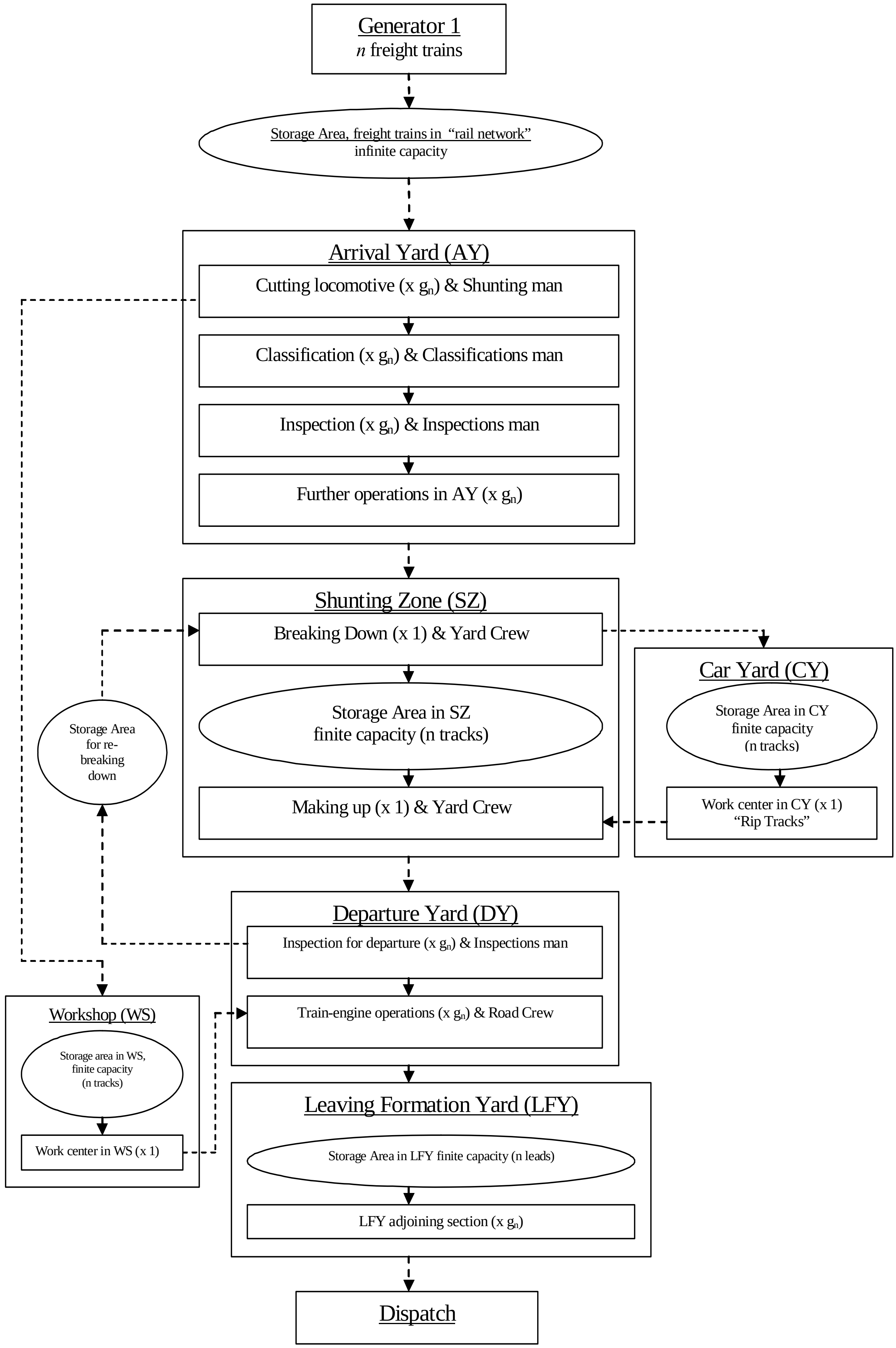
Therefore, for the objective of this discussion event simulation is suggested. More precisely, in this paper a simulation modelling methodology for analyzing and evaluating yard performances is provided. The decomposition approach is applied, meaning the yard in question is divided into sub-areas so that each area is examined separately. Of course, one should not forget that all the yard areas belong to one network.

In the following section a discussion on modeling yard performances by event simulation language SIMUL 8 is provided.

YARD SIMULATION MODELLING METHODOLOGY

The adapted concept for simulation of the operating processes with freight trains at formation yards is to follow the throughput (production) line of the formation yard being examined.

Figure 1 Yard Throughput Line



In Figure 1, a detailed scheme of the throughput line of the formation yard is presented. The throughput line of the yard is identified by a set of interconnected consecutive and/or parallel operating processes at the different areas of the formation yard, discussion of which comes next:

i. There are *n* freight trains spread throughout the railway network that are to be served by the formation yard being examined. The freight trains are replicated as a flow and in SIMUL 8 environment they are generated by tool called "Work Entry Point". Depending on the objectives of the study the generation of freight trains may follow probability distributions, or may follow strict fixed pattern permitting some random fluctuation. A measure that one obtains is the number of freight trains generated for a certain period of time (i.e., the period included in the simulation experiment).

ii. After having generated the freight trains, they are located over the railway network. To represent this property in SIMUL 8 environment one creates a Storage Area characterized with infinite capacity, and hypothetically speaking this is where the freight trains stand while waiting to be served by the yard being examined. This is required because once the freight train is on the road, the train cannot be cancelled; the train can be delayed in cases of "*en route*" perturbations or an oversaturated yard that is not able to accommodate it immediately. Then the freight train is forced to wait outside of the yard limits. Thus, to observe this phenomenon, such a Storage Area is inserted. The measure of performance observed is the number of freight trains in the railway network that requires service by the formation yard being examined.

iii. Freight trains arrive individually, one by one on the arrival yard tracks where a set of operations is fulfilled. One considers operations, such as: cutting the locomotive from the freight train composition; classification of freight cars; technical and commercial inspections; etc. In simulating with SIMUL 8, each operation is represented by a set of *g* equal Work Centres. The service patterns are to follow probability distributions. In fulfilment of each operation the responsible employee is required. The responsible employees for the simulation are set up by "*Floating Resources*" and one assigns e.g., for fulfilment of cutting the locomotive from the train composition a shunting man; for classification of freight cars a classifications man; for technical inspection an inspections man; etc. One obtains: Measures of *work centre* performance, such as: Number of freight trains completed; as well as the percentage of time for which a given work centre is either awaiting a freight train, working, blocked or stopped. This is visualized by pie chart. A measure of *floating resource's* performance that one obtains is its utilization in percentages.

iv. After having completed the service at Arrival yard the freight train is prepared for breaking down and the freight train proceeds to the Shunting zone. The shunting zone is divided into two parts. The first part is dedicated to breaking down and this is where the rearrangement process begins. Technologically, breaking down means that the freight train is spread out in peaces on a limited number of tracks in order to be easily regrouped by the next technological system, which is dedicated to making up of freight trains. Those freight cars found to have defects, or not in a current need are set off to "Car Yard" area for storage and/or repair. Later on when those freight cars are technically ready and/or there is need for them in the daily service they are to join the rearrangement process at the technological system dedicated to making up of freight trains. The whole set of operations in the Shunting Zone is fulfilled by Shunting Brigade, or simply said Yard Crew. Thus, to replicate the rearrangement process in SIMUL 8 environment one inserts one Work Centre dedicated to breaking down process; and one Work Centre dedicated to making up process. The service times can be replicated by Normal or Uniform Distribution with upper and lower bounds. In order to replicate a limited number of tracks one inserts Storage Areas characterized with finite capacity that equals the available number of tracks. The Car Yard is replicated as one Storage Area with finite capacity and one Work Centre. The measures of *work centres'* performance are the same as in the previous paragraph. The *floating resource* here is the Yard Crew and one observes its utilization in percentage for the time period of the simulation experiment.

v. The next technological subsystem is dedicated to the operating processes with freight trains at Departure Yard. At this technological system the freight train is prepared to depart. One considers two main sets of operations, such as: inspection for freight train departure; and freight train - engine operations. An *inspection for departure* consists of mechanical inspection of the freight cars and commercial inspection of the freight. Freight *train - engine operations* consist of arriving and putting locomotive on train composition as well as full brake test[1]. For fulfilment of those two sets of operations one sets up *floating resources*, such as: inspections man and road crew. An important element is that during the technical inspection defects or other faults on the freight train composition might be detected. In such an awkward situation re-breaking down is required. Thus, the operating processes at the departure yard are represented by two technological systems. One system dedicated to inspection for departure and another dedicated to train-engine operations.

vi. A crucial element that requires some additional care is the locomotive service at the formation yards. The locomotives are generally served in separate areas of the yard. Such areas are called Workshops or/and Roundhouses. The locomotives are specified by categories, manufacturing series, specific properties and technical characteristics. They are the engine of the freight train composition. In railway terms, each individual locomotive is called "unit". An engine of freight train may be a single unit or several units coupled together in multiple where more power is needed for the sake of the freight transportation service. Coupled in multiple means coupling units to the locomotive consist, at either the rear or between operating unites. Other subject is that of the *shut down locomotive*. Locomotives that are shut down are known as *dead engines* and this usually occurs when a locomotive is required in some place on the railway network and cannot be utilized as a prime mover (prime mover means a main generator for pulling the freight train) because there are not enough freight cars to be pulled in this direction and the locomotive should make a *non-revenue run*. To economize such a non-revenue run, engines may be moved dead in freight trains between the freight cars. Such a locomotive cannot have the break system operating and must be transported like a boxcar, cutting out the control of the brakes. However, in practice non-revenue runs cannot always be avoided.

For the objectives of this discussion, one considers that after having pulled the freight train composition into the arrival yard the locomotive is cut off from the freight train and sent to the technological system: "Workshop". There the locomotive undergoes a mechanical inspection that consists of verifying the technical readiness of the locomotive, checking the fuel if diesel, water and other technical conditions. After having the inspection done the locomotive is prepared for its next assignment. These processes in SIMUL 8 are replicated, as follows:

-The workshop is characterized with limited capacity and that is replicated by inserting one storage area with finite capacity, which equals the maximum number of locomotives that the workshop can accommodate. Measures that one obtains are: number of locomotives entered in workshop; number of locomotives currently waiting for a mechanical inspection as well as queuing times which may be demonstrated by a histogram.

-The service at the workshop (roundhouse) is represented by a Work Centre. The service times are to follow probability distributions. In CP Carga terms, the responsible employee for checking the locomotive technical readiness between subsequent assignments is the engineer who will drive the locomotive. If there are faults ascertained and the locomotive is not in technical readiness to fulfil its next assignment, the locomotive might need a heavy repair. In such an awkward situation, the locomotive is withdrawn from service and is pulled dead to a terminal that has a repair-shop. Measures obtained are: Number of locomotives currently in the workshop as well as Locomotives served by the workshop.

vii. Every freight train requires an engine. To equip a freight train with locomotive(s), "train-engine operations" are needed. Let us be reminded that these operations consist of arriving and putting a locomotive on a train composition as well as a full break test. Theoretically speaking, in the technological system dedicated to train-engine operations, the locomotive and already assembled freight cars are set together. The freight train is finally composed. In order to replicate such a detail in SIMUL 8 environment one activates the discipline "Collect" in "Routing in" menu. Measures of performance observed are as follows: Number of freight trains completed per technological system; Number of freight trains currently in the technological system; Queuing times as well as the percentage of time for which the technological system is either awaiting a freight train and a locomotive to be

[1] Full brake test is a detailed inspection of the brake system. Brake pipe leakage must not exceed the norm. All of the brake rigging of each car must be properly secured and must not bind or foul. Retaining valves must be in operating condition. The brake cylinder piston travel of each car must be adjusted to within the limits prescribed for that specific equipment. [9]

merged; working; blocked; or stopped. This is also displayed by pie chart.

viii. After having completed the operations at the departure yard the freight train is ready to leave. Then, the freight train needs permission, meaning a slot on the assigned adjoining section. Giving a slot depends upon the organizational pattern of the movements of all categories of trains as well as the traffic rules over the assigned adjoining section. Consequently, the freight train might wait for a while before leaving. Since every freight train has a particular assignment, the train is to leave the yard on a defined lead. One replicates this by inserting: one Storage area characterized with finite capacity that equals the number of leads; and a Work centre to replicate the execution of operation on leaving of freight trains.

ix. As soon as the freight train leaves, its service at the formation yard ends. In order to declare the simulation design of formation yard as "completed" one inserts a Work Exit Point. This is an ending technical aspect in simulating with SIMUL 8 and might be defined as a "Dispatch". Results that one might observe in Work Exit Point have the same meaning as measures of formation yard's performance and these are: number of freight trains completed for the time period of the simulation experiment as well as time in formation yard. One is able to display such results by a histogram showing the distributions of time of freight trains in the formation yard being examined.

VALIDATION

Implementing the foregoing methodology one creates simulation models replicating formation yard behaviour on the basis of which runs simulation trials with the purpose of analysing and evaluating the throughput level of the yards through a set of measures of performance (MOPs). Also, depending on the number of freight trains to be served and their arrival patterns at the yard being examined one identifies the "saturation" point at which one or more of the technological subsystems of the yard under study are blocked (oversaturated). This replies to the maximum processing capacity of the formation yard subject to technical characteristics, resources involved, and work technology incorporated at the production scheme of the yard.

A complete screenshot of the animation window of SIMUL 8 in simulating the operating processes with freight trains at a formation yard can look similar to Figure 2. The created flouting resources that do jobs in some of the technological subsystems are grouped on the left and we are able to obtain and observe the levels of their utilisation e.g., Chart 1, as well as other meaningful measures of yard performance. E.g., Chart 2 examines the effect on yard queueing times with increases in the freight train arrivals.

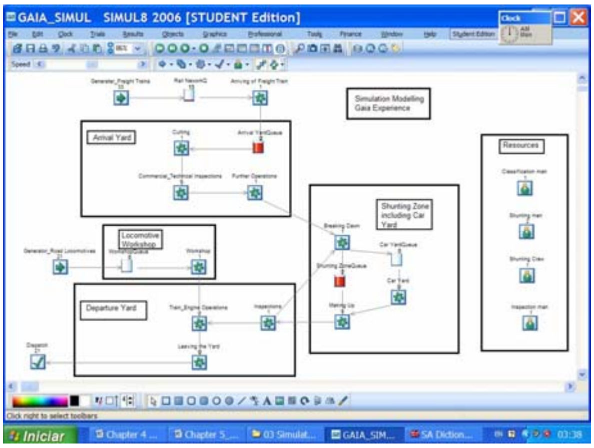


Figure 2 A SIMUL 8' Animation Window in Modelling the Operating Processes with Freight Trains

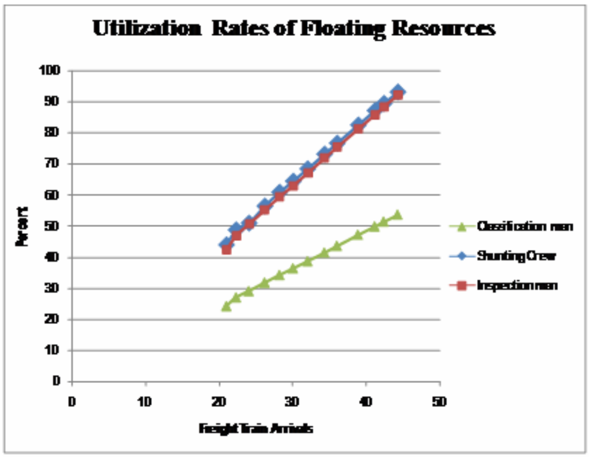


Chart 1 Effect of Increasing Freight Trains Arrivals on Utilization Rates of Floating Resources

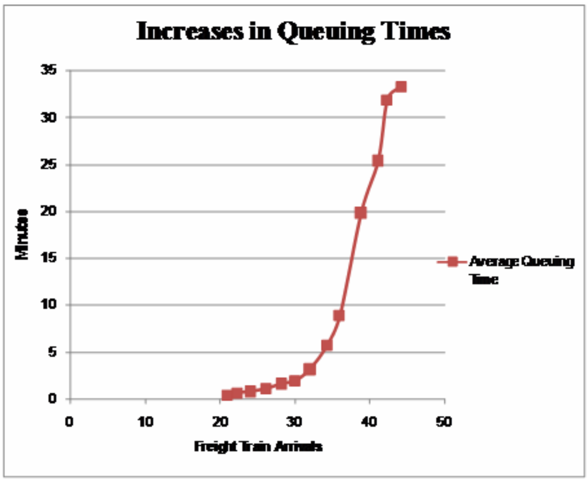


Chart 2 Increases in Yard Queueing Times with Increases in Freight Train Arrivals

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ИМИТАЦИОННО МОДЕЛИРАНЕ - МЕТОДОЛОГИЯ ЗА АНАЛИЗИРАНЕ НА ОПЕРАЦИИТЕ В ТРИАЖНИ ГАРИ

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Резюме: *Представен е визуален имитационнен модел на триажна гара. Моделът е създаден и приложен посредством компютърен пакет за дискретно моделиране СИМУЛ 8 (SIMUL 8). Използван е подходът на декомпозиране, при който триажната гара е разделена на отделни паркове. Това позволява изучаването на всеки парк поотделно. Имитационният модел придобива формата на мрежа от системи за масово обслужване. Компонентите на тази мрежа са взаимносвързани системи за масово обслужване (СМО), които взаимодействат помежду си и влияят една на друга. По този начин не се пренебрегрва отчитането на глобалното въздействие между железопътните товарни операции в триажната гара. Отделните системи за масово обслужване се състоят от работни центрове (обслужващи устройства) и буфери (места за чакане) и имитират поведението на отделните паркове. Така приложеният метод позволява изучаването на преработвателната способност на триажните гари.*

Ключови думи: *железопътен товарен транспорт, триажна гара, имитационно моделиране*