USE OF DISCRETE EVENT SIMULATION FOR A LONG RANGE PLANNING OF AN EXPEDIDITON SYSTEM

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ABSTRACT

Discrete Event Simulation is widely used in many areas both in industrial and non-industrial ones. It can be used as an operational tool or as a planning tool. Historically it is most used as a planning tool. Focusing discrete event simulation as a planning tool, generally it is used as a tactical planning tool, and its results should be implemented in days, weeks or months. There are fewer cases that employ discrete event simulation as a long range planning tool. This works is regard a long range planning study of an expedition system by means of discrete event simulation of a factory that produces customized metal sheets (special steels). After the study was performed it was possible to confirm that the initial configuration works for the forecasted growth of flow of the expedition system and that discrete event simulation can also be used as a long range planning tool.

Keywords: Discrete Event Simulation, Long Range Planning, Expedition System

1. INTRODUCTION

Discrete Event Simulation is widely used in many areas such as Public Systems (health care, military), manufacturing, call center, transportation systems, computer system performance and others (Banks et al. 1996). It can be used as an operational tool (e.g. as a factory scheduling tool) or as a planning tool (to validate a new system configuration for example). Historically it is most used as a planning tool, when the simulation project is punctual and is used to support a decision. After they supported a decision they "can be thrown away". But there are also "operational simulation models" in which the model should be used in an ongoing basis, i.e. they are reutilized. Refer to Pidd and Robinson (2007) for a detailed classification of simulation model practices.

Focusing discrete event simulation as a planning tool, generally it is used to validate a concept or to optimize the performance of a system before its implementation. So it is generally used as a tactical planning tool, and its results should be implemented in days, weeks or months. There are fewer cases that employ discrete event simulation as a long range planning tool, with the results to be implemented in years.

This works is regard a long range planning study of an expedition system by means of discrete event simulation of a factory that produces customized metal sheets (special steels). For confidentiality the name of the company should remain unmentioned. The major concern here is to answer if the proposed expedition system will support the growth of volumes until 2020.

The scope of simulation comprises the entrance of the expedition trucks (there are 3 basic kinds of trucks) inside the border of the factory, the entrance weighting process (at the balance), the loading process, the truck cover process and the exit weighting process (at the balance). The actual expedition system has 1 balance, 1 pit for loading and 1 pit for covering the truck (the configuration of the truck used demands to cover it after the loading process). The proposed system for a 235% growth of the flow would be 1 or 2 balances, 3 pits for loading and 2 pits for covering, and this should be confirmed. The team decided to confirm this project by means of discrete event simulation.

This paper is organized as following: section 2 makes a brief review of simulation methodology; section 3 presents the conceptualization phase and data collection; section 4 describes implementation issues; section 5 deals with the analysis of simulation results and section 6 makes the conclusions.

2. SIMULATION METHODOLOGY

Simulation Methodology or Process, describes the steps of activities that the modeler should perform in order reach a successful outcome. A classic one is described in Law and Kelton (2000) and it is depicted in figure 1.

Briefly, step 1 is problem definition, when it is necessary to define the objectives of the study and other specific issues. Step 2 concern with the data collection (if exists) and the creation of the conceptual model. Step 3 validates the conceptual model, while step 4 implement the model (i.e. create a computerized model). Runs should be made (Step 5) and a validation process should take place (step 6) to guarantee that the model represents the real system. Experimentation is focus of the steps 7 to 10 with the documentation and presentation of the study in step 10.

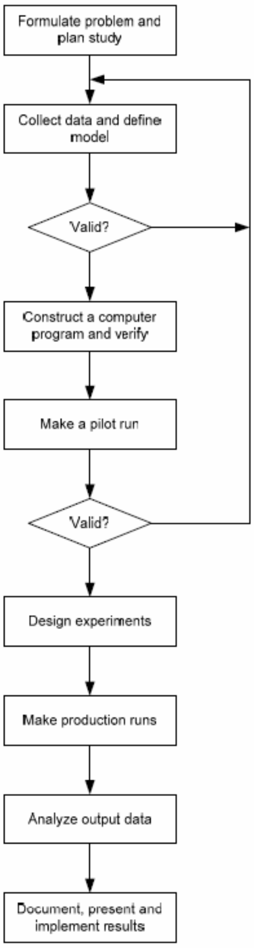


Figure 1: Process of Simulation
(Adapted from Law and Kelton, 2000)

However, in practice, a simulation study does not advance in such a linear and step by step way. In fact there are parallel activities such as implementation of the model and verification, and returns. For instance, the conceptual model or the data collection (or both) should be reviewed if the validity of the model could not be proved. Robinson (2004) confirms this non-linearity presented in simulation studies, despite of the simulation text books shows always linear processes. Another point is that all of this systematic process can be of no use, if the problem is no well understood and identified (Paul et. al 2005).

In this project we used the simulation methodology by applying the following steps: development of conceptual model, data collection, model building (actual), model verification and validation, model building (future) and analysis. It can simply be divided into 3 parts, such as: model conceptualization, model implementation and model analysis. So the in the next tree sections, we will cover each of these macro steps.

3. MODEL CONCEPTUALIZATION AND DATA COLLECTION

So first the conceptual model was discussed with the project team in a meeting of almost 5 hour (the project team was composed by an external simulation consultant, 2 company's engineers and 1 logistical supervisor).

Basically the model took into account the expedition flow of trucks and the flow of raw materials. In this latter case, despite the focus of the study is the expedition trucks, the raw material and administrative material trucks will be also considered in the model, because they share the same resources (balance). However they will have an overall permanency time inside the simulation, instead of the detailed modeling of its logistic process. Therefore the main process was of the expedition trucks and it comprehends the following steps:

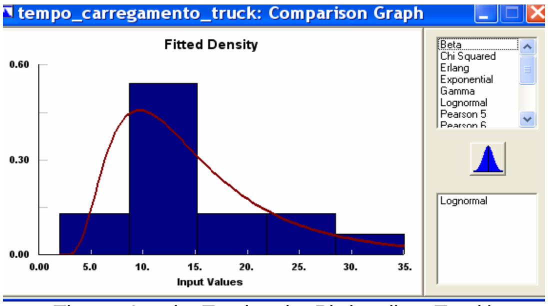
1. Entrance of the expedition trucks (there are 3 basic kinds of trucks) inside the border of the factory;
2. Entrance weighting process (at the balance);
3. Travel time to the pit
4. the loading process, at the pit;
5. the truck cover process, at the cover point;
6. Travel time to the balance
7. Final weighting process (at the balance).

As other factors that affects directly the results of the simulation were: the time window for the arrival of trucks, seasonality factor (to consider the concentration of flow at the end of the month), and the growth factor (as described before this would reach 235% by the year 2020). In this model it was also considered the truck limit inside the expedition area, which controls the flow of trucks (if the number of trucks reached this limit, they should wait outside). It was also considered the rain profile, since when it rains, the covering process is made inside the loading pit, thus affecting its utilization. This was considered by defining the probability of rain in each hour trough the day. Regarding the profile of arrivals during the day, we waited to the data analysis to see how it will be modeled.

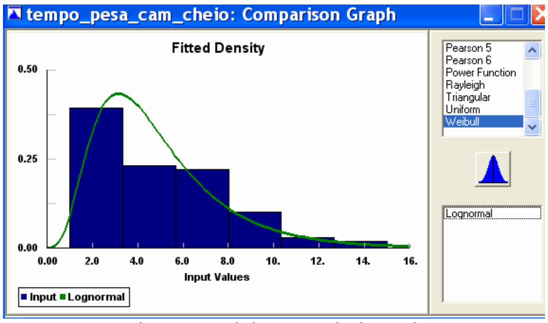
After defining the conceptual model, the data collection phase took place. In fact as mentioned by Pidd (1996), it is the model that drives the data and not vice versa. So we began to collect only data after the scratch of the initial conceptual model.

This lasted a period of 2 month and the following data was collected: trucks arrival flow (both expedition as raw materials trucks), time for the weighting process (with empty and full loaded truck), total permanency time for raw materials trucks, travel times (from the balance to the pits and vice versa), time for loading and time for covering (considering all kinds of trucks). It was found that the pattern of trucks is almost constant during a day (there was no peak concentration) so it was modeled simply with an exponential distribution.

These raw collected data were processed into a fitting software (Stat:fit) which generated the mathematical distributions. Figure 2 shows some Stat:fit analysis.



Time to Load a Truck a the Pit (medium Truck)



Time to Weight a Loaded Truck

Figure 2-Stat:Fit Analysis

The profile of the rain of São Paulo Region was found in Pezzopane et al. (1995). Table 1 shows the basic rain profile considered, in the months of January and February, that corresponds to the months with the highest pluviometric rate.

Table 1: Basic Rain Profile

Rain Probability	
from 00:00 to 1:00	9.7
from 1:00 to 2:00	11
from 2:00 to 3:00	9.4
from 3:00 to 4:00	8.1
from 4:00 to 5:00	9
from 5:00 to 6:00	9
from 6:00 to 7:00	7.7
from 7:00 to 8:00	6.8
from 8:00 to 9:00	6.1
from 9:00 to 10:00	4.8
from 10:00 to 11:00	5.5
from 11:00 ao 12:00	6.8
from 12:00 a 13:00	8.1
from 13:00 to 14:00	12.3
from 14:00 to 15:00	14.5
from 15:00 to 16:00	16.8
from 16:00 to 17:00	14.5
from 17:00 to 18:00	16.8
from 18:00 to 19:00	18.7
from 19:00 to 20:00	19.7
from 20:00 to 21:00	18.1
from 21:00 to 22:00	15.8
from 22:00 to 23:00	14.2
from 23:00 to 24:00	12.3

After the data was collected, we discussed also some considerations:

- Loading resources (man, forklift trucks) will be modeled without constraint, i.e., they will always be available at the pit.
- The travel time from the balance to the pit can be considered equal to the return (from pit to balance)
- The weighting time does not depend on the truck but on the state of the truck (empty or full)
- For the sake of the analysis it was considered the typical mix of trucks, i.e:22% of small truck, 62% medium truck and 16% large truck.

Next step was model building. This was done with the aid of Simul8 Simulation Software; which can be seen in next section.

4. MODEL BUILDING AND V&V

So the model of the actual configuration was developed (1 balance, 1 loading pit and 1 covering pit) in Simul8 Simulation Software vs. 2007. Since this model is not complicated it took around 8 hours to build it all. Figure 3 shows the initial configuration of the model, while table 2 shows the input data, which can be customized by the user. In this case all the times inside the model was migrated from Stat:fit to Simul8, but we made them not customizable for the client (they cannot alter its value).

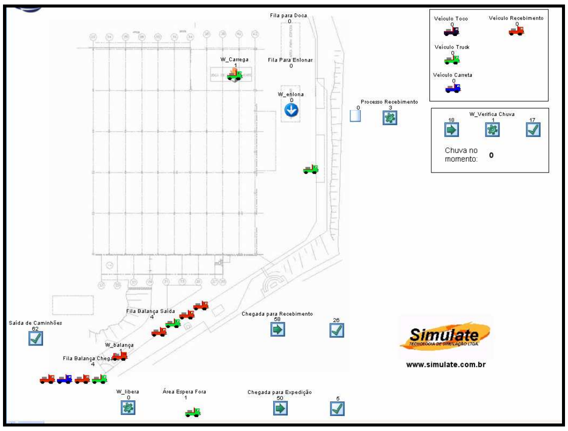


Figure 2 – Initial Model

Next phase was to validate its results against real world. It was set up a validation meeting with the team which last 3,5 hours. All the performance measures such as waiting times, queues size, utilizations were validated except one – the waiting time for loading. The simulation was shown that the truck waits less than in reality. So it was necessary to recollect the data, specially this measure to verify what went wrong. After one and half week of recollecting data, two points was discovered: that the initial queuing time was not measured and calculated by difference and that exist some wait due to other factors that the loading time.

These factors are many, including the time spend by the driver to make other duties, time to wait for the forklift trucks, but since we hypothesize that there will not be any constraints at the pit in the future configuration, these “waiting times” was not considered for the model. At this point the model was validated and we can proceed to the analysis phase. So the initial model was expanded to account for the extra number of pits and cover area. This is shown in figure 3.

Table 2 – Input Data Table

Simulation Data		
Expedition Truck Flows		
Average Truck per Hour	1.6	
Time Window (from-to)	2	23
Raw Material Truck Flow		
Average Truck per Hour	1.7	
Time Window (from-to)	6	21
Sazonality Factor	1.2	
Growth Factor	1	
Mix	%	
toco (1)	22	
truck (2)	62	
carreta (3)	16	
Truck Limit inside pit area	4	
Enable Rain?	0	
Rain Profile		
see table 1		

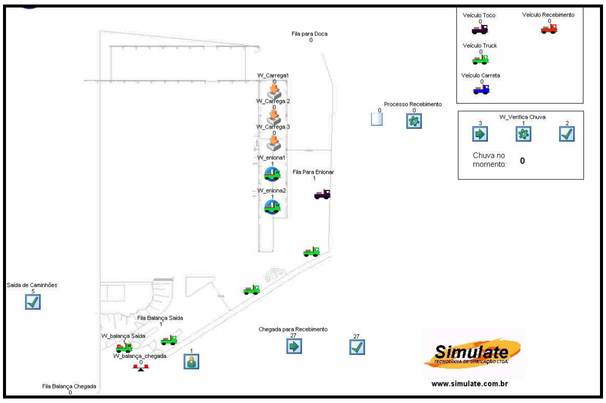


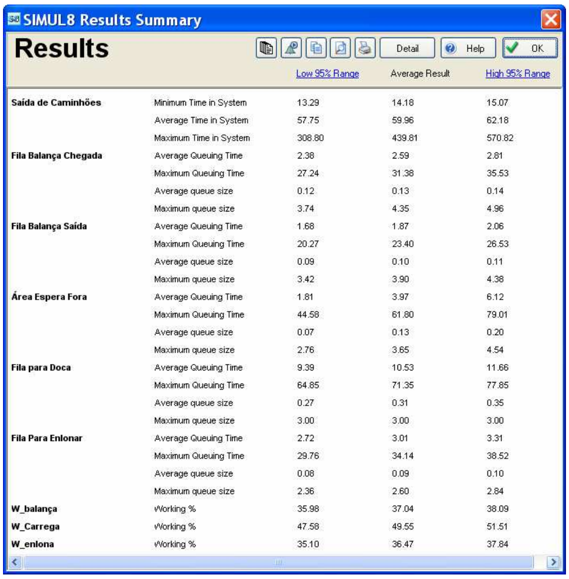
Figure 3 – Future Model

5. ANALYSIS

For the results analysis the main measures of performances adopted were:

- Minimum, Average and Maximum Time in System;
- Average and Maximum queue Size and queuing time for the balance entrance queue;
- Average and Maximum queue Size and queuing time for the balance exit queue;
- Average and Maximum queue Size and queuing time for the wait outside the factory (if the limit is reached);
- Average and Maximum queue Size and queuing time for the pit queue;
- Average and Maximum queue Size and queuing time for the cover area queue;
- Balance utilization;
- Pit utilization;
- Cover area utilization.

Figure 4, depticted these main results of one analyis, providing the confidence interval for 20 replications.


SIMUL8 Results Summary

Results

		Low 95% Range	Average Result	High 95% Range
Saída de Caminhões	Minimum Time in System	13.29	14.18	15.07
	Average Time in System	57.75	59.96	62.18
	Maximum Time in System	308.80	439.81	570.82
Fila Balança Chegada	Average Queuing Time	2.38	2.59	2.81
	Maximum Queuing Time	27.24	31.38	35.53
	Average queue size	0.12	0.13	0.14
	Maximum queue size	3.74	4.35	4.96
Fila Balança Saída	Average Queuing Time	1.68	1.87	2.06
	Maximum Queuing Time	20.27	23.40	26.53
	Average queue size	0.09	0.10	0.11
	Maximum queue size	3.42	3.90	4.38
Área Espera Fora	Average Queuing Time	1.81	3.97	6.12
	Maximum Queuing Time	44.58	61.80	79.01
	Average queue size	0.07	0.13	0.20
	Maximum queue size	2.76	3.65	4.54
Fila para Doca	Average Queuing Time	9.39	10.53	11.66
	Maximum Queuing Time	64.85	71.35	77.85
	Average queue size	0.27	0.31	0.35
	Maximum queue size	3.00	3.00	3.00
Fila Para Enlonar	Average Queuing Time	2.72	3.01	3.31
	Maximum Queuing Time	29.76	34.14	38.52
	Average queue size	0.08	0.09	0.10
	Maximum queue size	2.36	2.60	2.84
W_balança	Working %	35.98	37.04	38.09
W_Carrega	Working %	47.58	49.55	51.51
W_enlona	Working %	35.10	36.47	37.84

Figure 4 – Simulation Results

The first analysis performed was a saturation analysis, and this tries to answer the following question: “Considering the actual configuration (1 loading pit and 1 covering pit), how much increase of traffic does the system support”. We found that the actual configuration can be sustained for 3 years, and after that the performance of the expedition will degrade. Then the model was expanded to consider up to 3 loading pits, up to 2 covering pits and up to 2 balances (see Figure 3).

Several scenarios was build to account to the combination of the following variables: increase of flow, number of balances, number of loading pits, number of covering pits, presence or absence of rain, rain profile (normal or heavy) and mix of trucks (small, medium and big). Since the Basic Rain Profile (which we called normal) affects little the utilization of the pits, we decided to create a scenario with “heavy rain”, that increases the probability of rain within a given hour of the day.

The results showed that with the growth of flow forecasted to 2020, it was necessary 2 balances, 3 loading pits and 2 covering pits (exactly the configuration initially proposed). In this case, if we not take into consideration some exceptions, the system performed very well - utilization of pits is around 50%

and waiting times is around 1 min (medium) and 30 minutes (maximum). Only in some very particular circumstances when there are heavy rain or there are a concentration of arrival of big trucks the system become saturated, but in normal operation (98% of the time), the system is well sized.

6. CONCLUSIONS AND FINAL TAUGHTS

This paper covers the study of the expansion of an expedition system of an industry that produces metal sheets up to 2020. This study was conducted by means of discrete event simulation. After applying the simulation methodology, it was possible to assure that the initial configuration will work for the forecasted growth of flow of the expedition system, confirming the engineers' expectations. It is also confirmed that discrete event simulation can also be used as a long range planning tool.

The model was given to the company and they can run it on the Simul8 Run Time Version – Simul8 Viwer. So they can perform further analysis beyond the ones covered in this study.

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