Fitting out machinery for reference change in a hosiery plant: a DES approach

Melany Cristina Viana-Campiño

Camilo Higuita-Carvajal

EAFIT University
Medellín, Colombia
mvianac@eafit.edu.co

***Abstract*—** In this document is presented the results of simulating through a discrete event simulation model the process of fitting out machinery for a knitting plant in a hosiery company, in order to understand how this process work. The implementation and simulation of this model was done using the software Simul8 and considering four scenarios, the real and three proposed scenarios varying the main variables.

Key words* —*Fitting out machinery; knitting process; hosiery plant; discrete event simulation

I. Introduction

The hosiery industry is on charge of all the processes relevant with the elaboration of socks from the transformation of yarn to a hose using knitting machinery to the termination processes such as stamping, needlework and non-skid technology.

In the hosiery industry, the fundamental process is to knit the sock; this is knitting a large amount of threads, giving form to a design previously developed. To knit a sock is necessary a single machine and it takes approximately one minute, but even if the process is really difficult (because it depends on the complexity of the sock, the number of colors, the length of the sock and many other variables) it hardly would take more than three minutes.

For a hosiery plant that produces hundreds of different references in small batches, fitting out a machine for changing the current reference may take considerable time and it depends on several aspects:

- Design specifications: Length of the sock, number of colors, number of needles, striped design, among others
- Known reference / New reference
- Change variables: Different tissue type, increase in the number of threads, among others

Besides this, there are other factors affecting productivity and speed of the process. These include uncertain demand i.e. stochastic nature, the amount of resources available, the use that is given to these and experience of the staff.

On the other hand, discrete-event simulation (DES) is a simulation approach with four key elements: activities, queues, entities and resources. DES models a system as a set

of individual entities moving through a series of queues and activities in discrete time (Tako & Robinson, 2009).

In these order of ideas, is intended to implement in Simul8 a DES model for the process of fitting out machinery for changing production batches for different references in a hosiery plant with 816 places to locate knitting machines and hundreds of references in its portfolio. This model will allow to analyze this process and the time a machinery set is stopped because of this. Some analysis may also be performed on the distribution of the staff required for the changes.

Using DES for modeling this process is mainly justified because the attributes of the entities can be randomly generated and detailed monitoring to entities can be performed (Gunal & Pidd, 2005).

Another general feature of the models analyzed with discrete-event simulation is that focuses on areas and specific system problems and use historical information from the process (Lane, Monefeldt, & Rosenhead, 2000).

This document is organized as follows: in section II is formally presented the issue to study, in section III is described the methodology to follow and in section IV are presented the results and the conclusions.

II. Issue description

A. Issue statement

It is considered a kitting plant that works 24 hours by day, in three shifts of eight hours each one and is organized in 13 corridors with place for 48 machines each one. In this plant, the process of change the reference that a machine is kitting by other is done under the next methodology.

A production batch is scheduled to a machine that may or may not be working, in this moment a transfer order is generated to the warehouse that send the raw material for the kitting process to the plant in a trolley. When the machine isn't

working and the raw material is available in the plant, the new batch production is generated and an operator thread the machine for kitting the new batch. Once the machine is threaded a mechanic fit out the machinery according to the design and technical specifications of the sock.
In general, the process of fitting out the machinery is developed in five steps:

- Locate and change the parts of the machine
- Develop the design of the sock in a specific software depending on the type of machine
- Set the measures of the sock depending on the size required
- Test the machine and generate samples
- Validate samples

The target is to simulate the process of fitting out machinery using a DES model, for this, two variables directly related with the process are considered: change type and tissue type.

B. Resources

In the plant there are four types of technologies: Goal, techno, knit-close and double. In turn, each technology have different resources or machine types where a resource is different to another by the number of needles, the number of cylinders or the diameter of these.

C. Tissue type

In the plant are produced socks of eleven tissue types and changing parts of the machine depends on whether there is change of tissue type between the current and the previous reference.

D. Change type

Develop the design of the sock depends on whether the reference has been produced above, in this order of ideas, four change types are defined

- Repetition: The reference has been produced in the plant and the program has been developed for the specific resource
- New resource developed: The reference has not been produced in the plant before but the program is developed for the specific resource
- Resource change: The reference has been produced in the plant but the program has not been developed for the specific resource
- New: The reference has not been produced in the plant and the program hasn’t been developed

III. PROCEDURE

A. Data picking

For simulating the process two different data are necessary: inter-arrival and service times, for this, the next events of every change are selected

- Day-hour when the batch of the new reference is generated
- Day-hour when the machine is threaded
- Day-hour when the mechanic starts fitting out the machinery
- Day-hour when the mechanic ends fitting out the machinery

Once this events are saved, the data is classified in eight categories, depending on if the tissue type of the previous reference that the machine produced is the same tissue type of the current reference and the change type.
Table I presents the percentages of changes in each corridor, Table II shows the percentage of changes of each change type, Table III presents the percentage of changes of each tissue type, and Table IV shows the percentages of changes in each category.

TABLE I. PERCENTAGES OF CHANGES IN EACH CORRIDOR

Corridor	***Percentage***
1	11.65%
2	11.09%
3	10.18%
4	9.94%
5	8.58%
6	8.37%
7	7.93%
8	7.63%
9	7.17%
10	7.13%
11	3.55%
12	3.43%
13	3.35%

TABLE II. CHANGE TYPE

Change type	***Percentage***
Repetition	78.88%
New resource developed	9.41%
Resource change	8.61%
New	3.10%

TABLE III. TISSUE TYPE

Tissue type	***Percentage***
Smooth	59.44%
Half sandwich towell	25.48%
Sandwich towell	8.71%
Corrugated	2.85%
Links Links	2.05%
Links-Jacquard	0.33%
Jacquard	0.30%
Terry towel	0.25%
Others	0.60%

TABLE IV. PERCENTAGES OF CHANGES IN EACH CATEGORY

Category	***Change type***	***¿Previous tissue type = Current tissue type?***	***Percentage***
1	Repetition	True	54.83%
2		False	24.05%
3	New resource developed	True	6.97%
4		False	2.44%
5	Resource change	True	6.36%
6		False	2.25%
7	New	True	2.26%
8		False	0.83%

B. Distribution fitting

For the simulation, nine distributions were fitted with the information collected. For the start point of the simulation the inter-arrival times where fitted with an exponential distribution. For the activity of fitting out machinery, the service times where fitted with lognormal, gamma and uniform distributions. Figure 1 presents the histograms for the inter-arrivals.

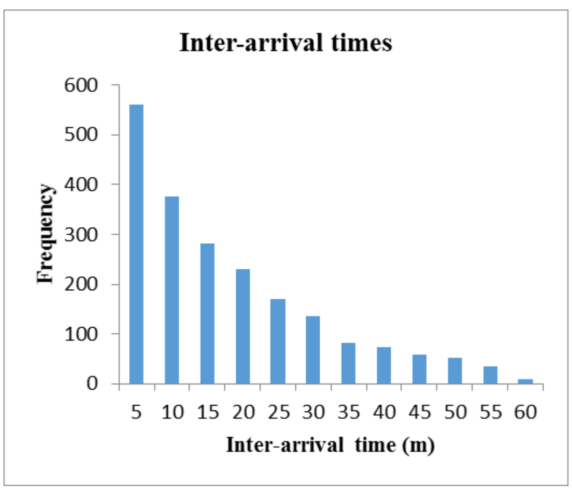

Figure 1. Histogram of inter-arrival times

C. DES model

This simulation approach considers four key elements: entities, resources, queues and activities. For the model, these are:

1) Entities: Reference change requirements
The entities are identified with labels from 1 to 8 depending on the category assigned for the simulation.

2) Resources: Mechanic staff

3) Activities: Fitting out the machinery
For this activity the service time of each entity is defined by the distribution that corresponds to the label assigned at the beginning of the simulation.

4) Queues: Queue for fitting out machinery

D. Scenarios

The model is simulated with four scenarios:

1) Real: This scenario considers the distribution of changes in the corridors as presented in Table I and assign a mechanic to each one.

2) Equitable distribution of changes: This scenario assumes that the changes and mechanics are distributed equally in all corridors

3) Resource change to repetitions: This scenario assumes that there are no Categories 5 or 6, that is, all references that have been produced have the program developed in the assigned resource, becoming repetitions. Also retains the distribution of mechanical as in Scenario 2.

4) New to new resource developed: This scenario assumes that there are no Categories 7 or 8, that is, all references that have not been produced before in the plant, have the program developed in the assigned resource, becoming new resource developed. Also retains the distribution of mechanical as in Scenario 2.

IV. RESULTS AND CONCLUSIONS

Table V presents the results for the average percentages of utilization of the staff assigned to each corridor running the Scenarios 1 and 2 in a simulation of 500 trials. From this table is possible to infer that the resources are not used all the time, as for Scenario 1 none reaches 100% utilization and workloads between the mechanics are significantly different. Even if the changes were equally distributed the average utilization percentage would be 72.38%.

Table VI presents the time in system of the changes for the Scenario 1 discriminated by categories. Observe that for each change type, always when the tissue type of the previous reference is the same than the current reference the average time in system is smaller than in the other case.

Table VII shows the results for the time in system in all the scenarios in a simulation of 500 trials.

From the results presented in this table, observe that only equally distributing the changes in the corridors, the average time in the system of each requirement decrease by 23.51%. Further considering the results of the Scenarios 3 and 4 that involves equally distribution of changes plus the prior development of designs of socks in the scheduled resource, the average time decreases by 28.16% and 25.21% respectively.

TABLE V. Average percentages of utilization of the staff in each corridor

Corridor	***Average***	
Scene	***1***	***2***
1	92.49%	73.08%
2	90.47%	73.04%
3	89.79%	73.01%
4	89.20%	73.12%
5	80.76%	74.17%
6	79.22%	73.25%
7	76.58%	72.47%
8	73.45%	72.28%
9	69.25%	72.51%
10	68.61%	72.19%
11	35.55%	72.11%
12	35.04%	71.95%
13	33.91%	72.91%

TABLE VI. Time in system for each category in Scenario 1

Category	***Average time in system***
1	589.09
2	610.36
3	677.12
4	913.45
5	847.73
6	1014.51
7	778.38
8	918.02

TABLE VII. Time in system for the four Scenarios

Scene	***1***	***2***	***3***	***4***
Minimum time in system	24.13	23.09	20.73	22.07
Average time in system	592.36	453.06	425.57	442.98
Maximum time in system	2649.35	2108.31	2007.76	2078.67

Currently the corridors are distributed by technologies, a way to balance workloads for the staff would be to combine resources from different technologies in all the corridors, even so, the resources would continue being unused. Additionally, an analysis of the versatility of the mechanical should be conducted, since learning generally focuses on one or two types of technology.

Because it is evident that the long time the requirements take are not due to resources, and that even with a equally distribution of the changes the average time in the system reaches almost eight hours, further analysis should be conducted in process of fitting out the machinery.

Results analized by category are consistent with the difficulty of each process, except for the last two categories, this may be due to sample quality, since these were not counted for over 50 data.

Other analyzes were done with the collected data, including a Gantt chart that displays how often each reference is produced in the plant, how long it takes to start the process of fitting out the machinery once the batch production has been generated, how long the process of fitting out the machinery takes and how long is this reference in production.

References

Gunal, M. M., & Pidd, M. (2005). *Simulation modelling for performance measurement in healthcare.* Paper presented at the Simulation Conference, 2005 Proceedings of the Winter.

Lane, D. C., Monefeldt, C., & Rosenhead, J. (2000). Looking in the wrong place for healthcare improvements: A system dynamics study of an accident and emergency department. *Journal of the operational Research Society*, 518-531.

Tako, A. A., & Robinson, S. (2009). Comparing discrete-event simulation and system dynamics: users' perceptions. *Journal of the operational research society, 60*(3), 296-312.