

OPTIMIZING A PRODUCTION LINE OF A PRINTING HOUSE IN MEXICO

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Abstract

In this paper, is described the use of simulation to determine the real production capacity of Centro Gráfico Industrial which is an important printing house at Mexico City. First it was necessary to obtain data from the company. Once this information was obtained five scenarios were developed as potential responses to improve. Based on the simulation results, a series of recommendations were made in order to maximize production rates and minimize time consumption for each process, and therefore optimize results on the bottom line in terms of average hours per order. This process can also be applied to similar situations in companies throughout the world to improve their competitiveness in increasingly demanding markets.

Keywords: Optimize, simulation, productivity, Mexico

Introduction

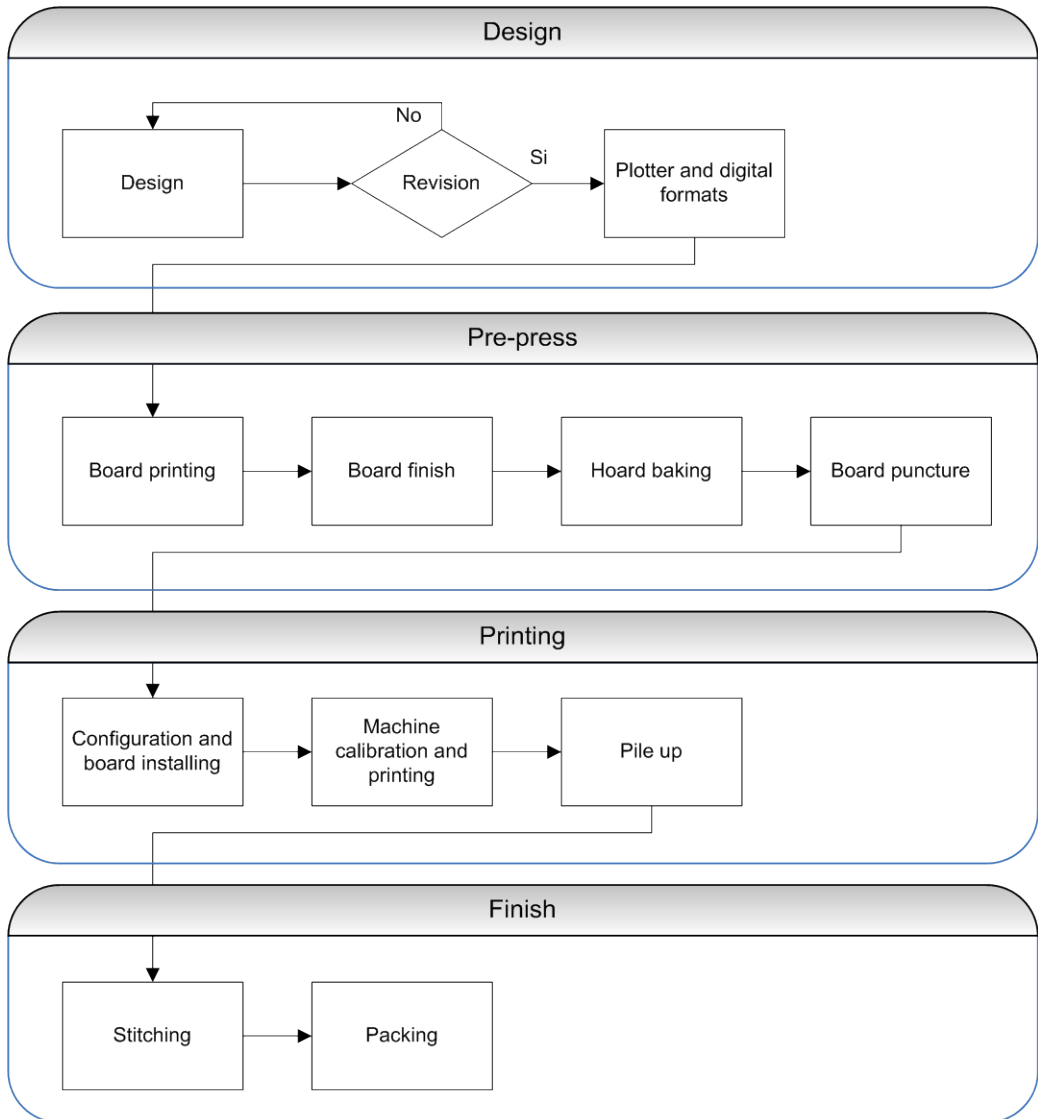
Centro Gráfico Industrial is one of Mexico's largest printing houses. It was founded in 1964 as Miguel Galas S.A., with bank check printing as its main business. Shortly after, the printer started to produce a larger variety of products including all types of marketing banners and printed publicity. In 1966 it produced all of the printed material for the 1968 Olympic Games.

The company needs to optimize the production line in order to increment the actual production rate without needing to make a substantial investment on new machines. This is a big challenge considering that company doesn't have any historical or statistical data regarding production rates, average time before a machine fails or average time before a machine is repaired. That is the reason why, the suggestion was to make a simulation model to emulate current and desired scenarios in order to make punctual changes in production or human resources.

The company's main operation line consists of four individual work stations (Figure 1). Each station is composed of several tasks carried out by

one or more workers and the corresponding machinery necessary to process the input.

Figure 1: The production line tasks grouped in the four work stations. Developed by the authors.



The first station is design, here is where the graphic art proposal is made, followed by the revision, plotter, printing and the digital format output of the final design proposal. Generally it comes out in terms of the final which could be a magazine, book or pamphlet.

Once the design proposal is approved, it is forwarded to the pre-press station. This is where the boards are made. Clearly, the boards are generated with the digital formats provided by the design station. Four different boards

need to be created for each sheet included in the proposal (one for each color) and each board is processed by four independent machines. This is a critical task because a minimal error could represent huge losses when passed to printing station. At this point even the smallest error would make a big impact on the production processes.

The boards are then sent to the printing station which is responsible for the actual massive reproduction of the product. The boards need to be installed on one of the available rotary machines. This process must be repeated for each sheet in the final design, normally, a sheet would equal four times a normal-sized letter paper. Most of the time of production is consumed in this station and here is where the biggest waste is generated due to a highly inefficient calibration system based on trial and error. It is so high that the average waste for a normal production would reach up to 20% of the whole raw material. Even though it is a high number, it is considered to be within the normal ranges. Nevertheless, it is important to take notice that an optimization in this process would highly accelerate the whole printing station.

Once all the sheets are printed, they are transported to the “finish section”. Here is where all the sheets are piled together to make up the final product which is packed up in groups ready to be delivered to the client. This process is carried out by 2 saddle stitcher machines (Muller Martini Bravo Plus).

With all the tasks conceptualized and grouped in stations, the first step in making a good and accurate simulation could be done: modeling the production line.

Once the model was developed, the next challenge was to obtain real data of each one of the tasks in the four work stations in order to generate the current production scenario. This is the input and the base for further scenarios generated across the case study.

System Description, Data and Variation Sources.

This is a quantitative and transversal study, which main goal is to determine the installed real production capacity of the factory. The results obtained by the simulation model would represent the optimal production ratio, which would be compared to the actual registered production. Based on this information and on observation, adjustments would be made to the model in order to obtain a better scenario in terms of output production. Each adjustment would be considered a parallel scenario. The scenario with the best results will be considered optimal.

Considering that the factory works 250 days a year, and the current real production ratio is X units per day, then 250X are produced in a year if downtimes and errors aren't taken into account, which would be the

theoretical maximum. In the real world, this number would be always affected by the MTBF (Mean Time Between Failures) and MTBR (Mean Time Between Repair), then:

$$OP(\alpha, \beta) = X' \dots\dots\dots(1)$$

Where *OP* is the optimum production rate, α is the MTBF, β is the MTBR and *X'* is the actual output produced working at a maximum capacity.

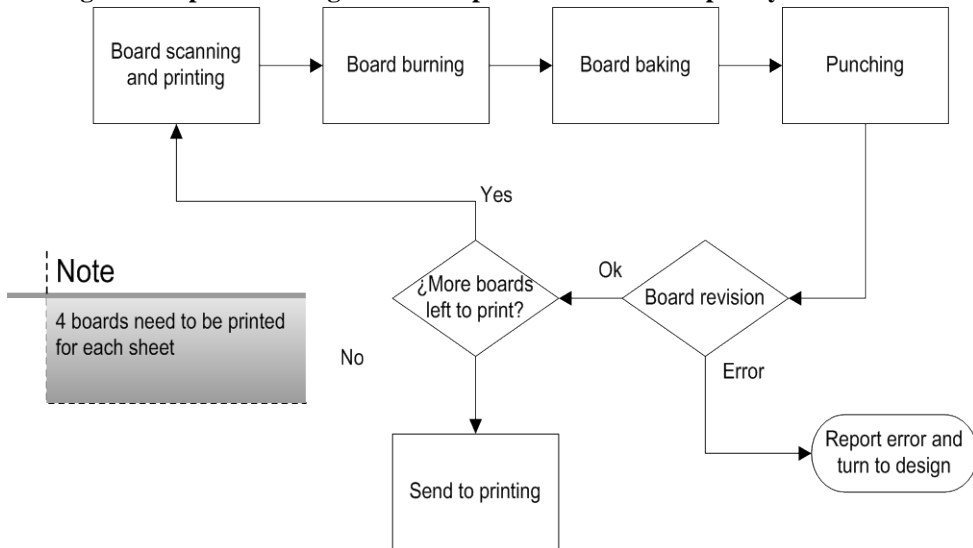
It is important to say that the adjustments proposed have certain limitations. They should only consider changes in certain process or group of processes, quality control, shift changes and or human resources. They mustn't consider acquisition of new machinery to improve the production capacity. Also, each scenario must minimize the sources of error and try to provide a solution when possible.

Resources and Operators

At the design work station the company has two designers responsible for the design proposal, and a supervisor who takes care of the revision of the designs. Each one has a personal computer and the final design in printed in an EPSON STYLUS PRO 10600 plotter.

The pre-press station consists of a PC, a series of three machines and a puncher tool. All of them are handled by a single operator, who is also responsible for the transportation of the boards to the printing station. The machines are as follow: KODAK board printer, KODAK Scanner, CREO Trendsetter 800 Quantum and a furnace.

Figure 2: Operation diagram in Pre-press station. Developed by the authors.



On the printing station two operators are responsible for the board bending and installation on the rotary machine. This is an important process

because a correct installation prevents further errors and waste in printing, which is also time consuming. Supervision is carried out by another operator who is also responsible for calibrating the machine until obtaining acceptable quality printing. The piling of the printed sheets is carried out by other two operators. The equipment on this station: Kimberly Klark paper, Bender, Harris Rotary Printer Mod. M-200, Koing & Bover Rotary Mod. C-215.

The finish work station is formed by 2 saddle stitcher machines Muller Martini Bravo Plus; each of which has 6 sub stations that can be used by one operator at a time, responsible for feeding the machine with printed sheets. There is one supervisor in this station and one more operator who handles the final product and carries out the packing.

There are three types of tasks carried out by the operators: The material handling operations (MH), the periodic operations (P) and the machine repair operations (MR) (Ankenman, Tongorlak, & Nelson, 2010). All operators must have MR or MH operations and almost everyone has a P task, which could be a quality revision, maintenance and error prevention. As expected, MR have the highest variability amongst all other tasks, MH are the most regular ones. MH are carried out by regular operators, these tasks are periodical and have a high frequency. Supervisors have more periodical tasks involving quality control and error prevention. These tasks should have a higher priority over the MH tasks. MR tasks should be carried out by special type of operators who must be qualified to repair the machine in case of failure. One operator should never be assigned MR tasks with two critical machines in order to prevent elapsed downtime in case of simultaneous failure on both machines. MR tasks always have the highest priority. MTBF and P tasks (revision and maintenance) are related in a direct way, the more periodical revisions are made, the higher the average time before failure.

Each operator or employee works 8 hours each shift, including 1 hour lunch break. All the machines are considered to work non-stop along the two shifts. The only reason why a machine shouldn't be working is because of maintenance, queues on previous stations, error reparation and lack of sales (which won't be the case in this study).

Variation Sources

Each machine is prone to failure. That's why is necessary to observe and compute the mean time before failure (MTBF) (Ankenman, Tongorlak, & Nelson, 2010). When a machine fails, it can't process any input and two things can happen: a) the conveyor stops and the input is queued. Or b) the conveyor is canalized to another available machine. Also is important to consider the mean time before a machine is repaired (MTBR). Once this data were collected on every work station and every relevant activity were considered, the simulation model could be done.

Simulation Model.

The simulation model was created using Rockwell Arena simulation software. That software was used because it is easy to handle and has the ability to create complex layouts and animations to represent all the processes. The model was created along with the distribution functions modeled also in Arena based on the captured data. The simulation model runs in terms of "Orders". Each order consists of a type of pamphlet, the pamphlet's length ranges from 1 sheet up to a maximum of 4 sheets. The probability distribution for getting each length is as shown in table 1.

Table 1: Order length probability distribution. Developed by the authors.

Length (Sheets)	Probability
1	10%
1.5	15%
2	30%
2.5	25%
3	15%
4	10%

For all the scenarios it was considered a constant order entry determined by a normal distribution of 1 with a mean value of 0.5, in terms of days. This is a fairly good number and will permit to identify where the queues are generated in our system. At the current scenario, the MTBF and MTBR are modeled as shown in table 2.

Table 2: MTBF and MTBR in first scenario.

Resource	MTBF (Hours)	MTBR (Hours)
Trendsetter	EXPO(32)	EXPO(0.5)
Scanner	EXPO(32)	EXPO(0.5)
KB Rotary Machine	EXPO(8)	EXPO(0.5)
Harris Rotary Machine	EXPO(8)	EXPO(0.5)
Muller Martini Bravo Plus 1	EXPO(16)	EXPO(1)
Muller Martini Bravo Plus 2	EXPO(16)	EXPO(1)

The complete production line layout as created in Arena is shown in the Figure 3. It's grouped by, first, the design and pre-press processes, then, the actual printing and finally, the finishes work station. In addition, to get a more graphic representation of what is going on, an animation was created (Figure 4) so it could be easy to identify the queues and the failures generated across the system in runtime.

Simulation Scenarios and Results.

As said before, the main indicator in the system are the orders processed. At the first simulation it was possible to determine which is the

maximum amount of orders that were able to be processed without creating infinite queues. This number is a normal distribution of one order each 7 days with a mean value of 0.5.

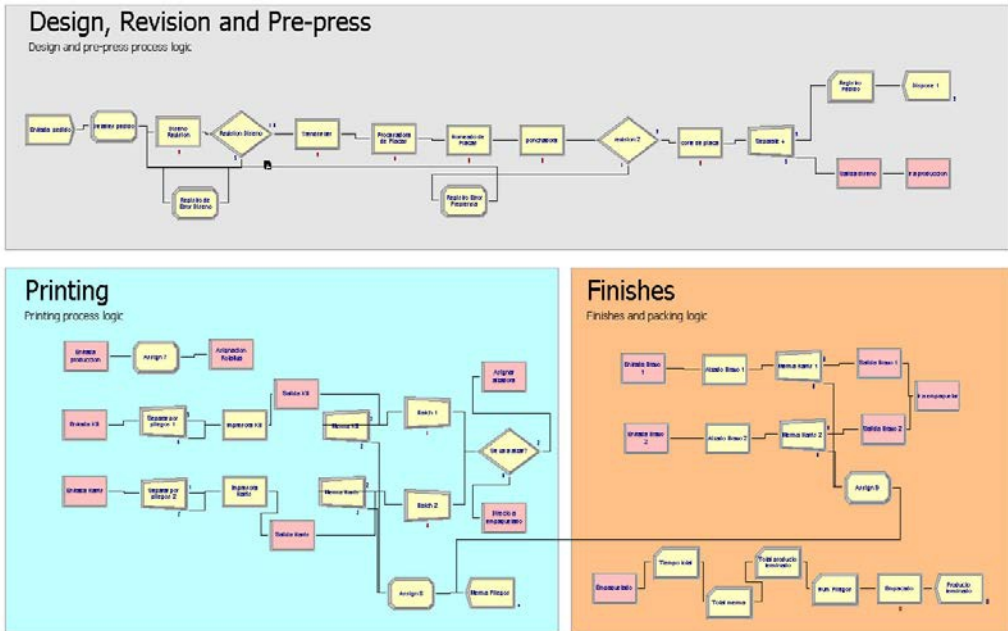


Figure 3: Complete system layout as modeled on Rockwell Arena. Developed by the authors.

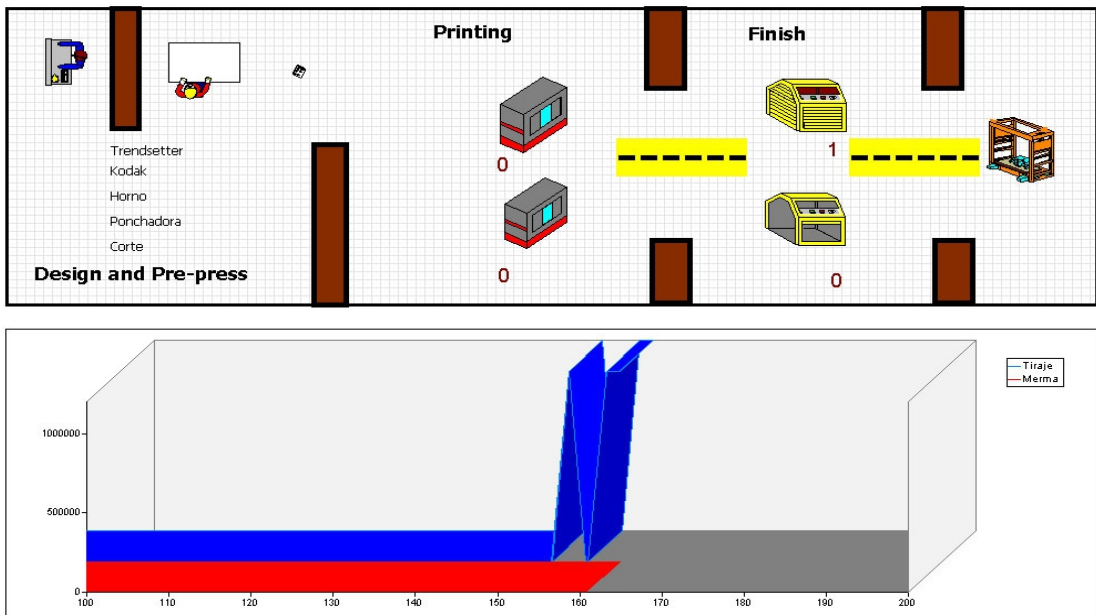


Figure 4: System simulation layout. Developed by the authors.

Analyzing the first (current) scenario, the results showed that the average processing time for each order was 750 hours. This is an acceptable time, in fact, is the real average time in which an order is processed, but the main goal was to model new scenarios in order to decrease the average production rate. It is important to note that the main process in the system is the actual printing. This is also where most of the time is consumed.

First Simulation Scenario

The first hypothesis was that the MTBR and/or MTBF were factors that would highly affect the production output ratio. That's why in the first parallel simulation model is depreciated the MTBR. In other words is supposed that each time a machine fails, it is repaired immediately and put back to work. Ther scenario was exactly the same as the starting one except MTBR equals cero.

As expected, the results were much better than the original scenario, the average time for each order dropped from 750 down to 420 hours. Now it is possible to determine how much the MTBR impacts the production output. Obviously it is impossible to have a MTBR of cero. That's why the model needed some adjustments in order to decrease the MTBR as much as possible.

Second Scenario: Minimizing MTBR and Maximizing MTBF

There were two approaches to reduce the machine inactivity due to failure. One was to reduce the MTBR and the other one to increase the MTBF, but maybe a better solution would be one that does both. Preventive maintenance for each rotary machine is the solution proposed. This would be performed by a group of three technicians every two Sundays. Because Sunday is a day of inactivity, the machines wouldn't have to be shut down, nor would it interfere with any activity in the station.

Based on research, it is safe to say that a minimum of 25% decrease in MTBR and an increment of 20% in MTBF can be reached by applying the solution afore mentioned. The reason the MTBR would decrease is because the maintenance would prevent major failures to occur, therefore most of the failures will be minor and could be corrected quickly. The scenario is exactly the same as the original one except MTBF equals EXPO(9.6) hours and MTBR equals EXPO(22.5) minutes. The results were very good. The average production time for each order was of 465 hours. In contrast with the original 750 hours, this is a big improvement.

Third Scenario: Minimizing Calibration Time

One huge factor that affects the production rate in the printing station is the calibration procedure. It is highly inefficient and due to this, 12% of

the total raw material is wasted. It is not just raw material that is lost here, also this is hugely time consuming because it is a trial and error based process. It is also important to note that the calibration must be repeated for each sheet that forms the pamphlet so for instance if company has the following order which is 4 sheets long, the print run equals r , the rotary machine maximum production rate is 50,000 sheets/hour but in calibration mode it is just 5,000/sheets/hour, and it is known that the total waste generated is around 12% of the total print run, that is $Waste = (0.12)r$ which can be huge. If the company wants to make an estimate about how much time this process consumes, is possible to do so with the following equation:

$$t = \frac{s * r * 0.12}{5000} [Hours] \dots\dots\dots(2)$$

where t represents the total calibration time in hours, s equals the number of sheets, r equals the total print run and 5000 is the number of sheets printed by hour in calibration mode. So, suppose company has $s = 4$, $r = 500000$, then $t = 48$ hours for the whole 4 sheets. That means that 12 hours ($48/4$) are spent each time the machine needs to be calibrated. That said the fourth scenario will try to minimize the average waste produced on each print run for both printer machines.

The proposed solution to the problem is to invest on training. Research on the theme (See Appendix A) showed that huge optimization could be made with the correct training, specifically on the calibration of the machines. In the best case scenario is possible to lower the waste from 12% down to 5%. This is too good, so instead the number used at this scenario was more conservative, 6.5%. The results were very good. The average production time for each order was of 640 hours; not as good as our previous approach, but significantly better than the original 750 hours.

Fourth Scenario: Combining Both Solutions

A smart approach would be to combine the previous two solutions, which showed great improvement in the output compared to the original rate. It is important to notice that for these solutions to succeed, the managers must make the decision to invest in the quality assurance program mentioned on the two previous scenarios.

The results were good but not as good as expected. The average production time dropped down to 454 hours per order. This means that it hasn't been reached the lowest value possible by making adjustments only on the printing work station.

Fifth Scenario: Optimizing Finishing Station

So far, it has been tried to optimize the printer station as much as possible, as it is the most important one and where most of the time is consumed, but there is one more station that also needs to be taken care of: The finishing station. More concrete, the Bravo Plus stitching machines.

The proposed solution is similar to the second scenario. That is to invest in preventive maintenance. Every other Sunday, three technicians should make a profound inspection of each one of the two machines in order to identify possible failures or erosion in machine parts that need to be replaced. The simulation scenario will increase the MTBF in 20% and the MTBR will decrease in 25% giving us the following distributions: MTBF: EXPO(19.2) and MTBR: EXPO(22.5).

The results were somehow expected. The average production time per order for this scenario is of 460. That means that the finishing workstation is not a bottle neck in the whole production process and therefore we can't minimize the time by optimizing this station.

Figure 5 shows the comparison between the five scenarios. Obviously the first one is not taken into account as it is a theoretical optimum where MTBR = 0, therefore it can't be considered a possible solution.

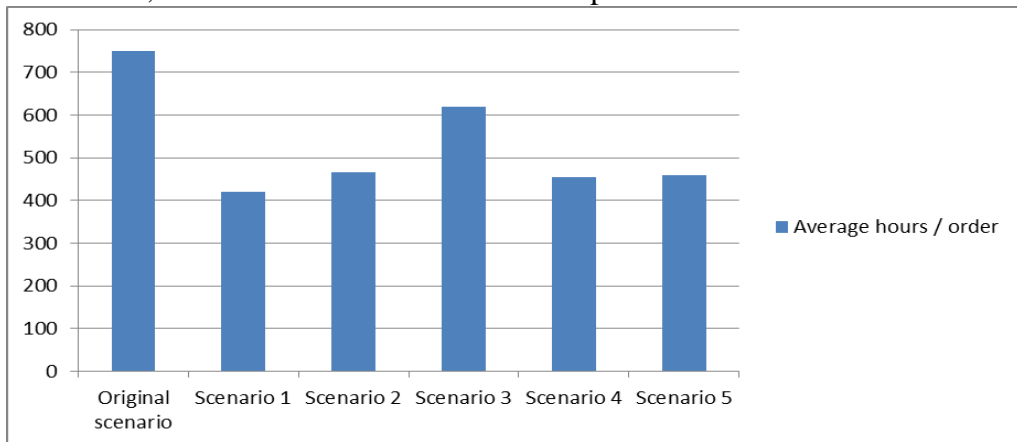


Figure 5: Graph comparing all six simulated scenarios. Y axis represent the production time in hours per order processed. Developed by the authors.

Conclusion

Simulation provides the company a very firm base for making decisions based on accurate information, information that is based on careful data analysis. In other words, simulation is the process of designing and developing a computer model of a system or process, and running experiments with it in order to have a complete understanding of the system or evaluate several strategies under which it can be operated (Shannon, 1975). If used correctly, simulation can provide accurate answers to the most common operation management questions in every company. Being one of

the strongest tools of operations research, usually simulation never comes alone, rather, its power resides on the correct data mining and manipulation based on optimization, probability, queuing, and decision analysis, among other fields.

Without using this important technique, it would be extremely difficult to identify where the weak points of our system are located, and therefore it wouldn't be easy to determine which improvements or executive decisions need to be taken in order to optimize the production which would have direct impact on the bottom line (Johnson, 2000).

As described earlier in this paper, simulation can make a huge difference in the production strategy not only for printing houses, but in every single system in which time and production efficiency are crucial to the business.

It is important to point out that simulation does not provide a solution itself, as seen on the proposed scenarios. An intern quality assurance program needs to be implemented. Not only will it optimize the machine failure rates, but it will remove the in-site sampling requirement and therefore create important savings of time and money (TSE Worldwide, 2011).

Some of the most important points learned throughout this project simulation are:

- ✓ The simulation accuracy lies on the precise data gathering. Imprecise data would invariably result in incorrect simulation results.
- ✓ The simulation model must always include every non-trivial process in the system, even though at first glance there doesn't appear to be a bottle neck in the production line.
- ✓ Focus not only on the output performance measures but also record measures that provide insight into where the problems might be occurring (Ankenman, Tongorlak, & Nelson, 2010).

Appendix A. Warm Up and Calibration Time in Printing Machines

As described earlier in the second simulation scenario, the printing machine warm-up and calibration is a big time-consumer on the production line. The data gathering and research on the company showed that for every sheet which forms an order, before the actual printing begins, a machine calibration needs to be done. This process basically consists of making the colors match up perfectly. The problem is that this is not quite a simple task. In fact, the research showed that up to 12% of the raw material is lost in this process. The average order length in sheets is about 2, and the average order size is about 500,000 copies. That means that if 12% is lost, 120,000 sheets

are lost in waste plus the time consumed to produce those 120,000 sheets, which is vast.

Research on the theme was made and it was discovered (Jurado, 2011) that the process could be optimized by minimizing the estimated waste percentage from the original 12% down to 5% which is the best case scenario. In this case it was define not to take such an optimistic number and go on with a 6.5% which is more conservative, but a very good figure in terms of savings in time and money.

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