Operations simulation in Recipharm's pharmaceutical warehouse

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Abstract

The performance of the supply chains is a determinant factor in the success of the companies. For such, and considering that nowadays the markets require higher service levels at a reduced cost, the warehouses/distribution centers have seen their importance strengthened within the supply chain.

This project consists in the analysis and the study to improve the operations executed in the warehouse of the pharmaceutical *Recipharm*. For this project it was used the SIMUL8 software to create a model which allows the simulation of the several procedures done by the major components of a product manufactured in the *Recipharm* Pharmaceutical. Three exploratory experiences were studied changing some inputs, such as the number of resources used at the sampling room, in the quality control of the finished product, and the number of factory production lines. Afterwards, and in order to present intermediate solutions, a multidimensional analysis was also studied.

The several experiments tested allowed the conclusion that the implementation of a second manufacturing line causes the reduction of about 6 days in the average time in the system, or in other words, in the mean time since the arrival of a manufacturing order until their dispatch as a finished product. Lastly, it has also been concluded that the increment of resources in the quality control causes more meaningful reductions in the average time in the system than increasing the resource availability in the sampling room.

Keywords: logistics management, warehouse management, simulation, discrete event simulation, pharmaceutical industry.

1 Introduction

Recently, the pharmaceutical companies have faced an increasing pressure to reduce the research and development costs (R&D), as well as the operational costs. Although the pharmaceutical industry investments are applied mainly in R&D, there are significant opportunities to generate economic value through improvements along the supply chain. (Laínez et al. 2012).

The increased demand in the last years, and the physical constraints of the warehouse justifies the need to reformulate the operations to obtain a more rational use of space, without jeopardizing the service level.

Therefore, the central objective of this study is to analyze and improve operations within the warehouse of the pharmaceutical company *Recipharm,* located at Queluz, in order to enable an activity increase in the manufacturing facility contiguous to the warehouse in a efficient (low costs) and effective way (keeping the current level of service).

2 Literature Review

2.1 Logistic Management

Over time, logistics has shown some changes coming from several areas which served to encourage its evolution. The military sector has been the one that most intensely marked the logistic development. The definition of logistics has evolved and has been modified at the same time it becomes a competitive factor in the business environment (Bowersox et al. 2012). Currently, the largest organization of academic professionals in the field, the Council of Supply Chain Management Professionals (CSCMP), defines logistics management as part of the supply chain management that plans, implements and controls the efficiency and effectiveness of forward and reverse flows, storage of goods, services and related information between the point of origin and the point of consumption in order to meet customer needs (Vitasek 2013). These developments occurred not only in the logistics definition, but also in the number of activities which includes. The number of activities related to goods, services and information has increased significantly (Lummus et al. 2001).

2.2 Warehouse Management

Warehouse management was for many years exclusively seen as a cost and not as an increased value for the companies, but nowadays is becoming a component of increasing importance within companies. The correct functioning of a warehouse is achieved when the client is completely satisfied with his order in relation to the delivery time (service level), as well as regarding to the price to pay. To make this possible, all logistics and warehouse processes have to be made in the shortest time possible, minimizing associated costs and with efficient use of available resources, which are always subject to uncertainty conditions (Karásek 2013). Resources such as space, manpower and equipment should be allocated among the various warehouse functions. Each function should be carefully implemented, operated and coordinated in order to achieve the system requirements in terms of capacity, efficiency and service, taking into account the minimization of resources used (Gu et al. 2007).

2.3 Simulation

The simulation is a technique that allows administrators to analyze systems in order to identify improvement opportunities or limitations which may make a difference in its overall performance. This type of tools help the process of analysis and make the decision-making more effective and efficient (Banks et al. 2014). Simulation refers to the broad collection of

methods and applications that mimic the behavior of real systems, usually using a computer with the appropriate software (Kelton et al. 2010).

For the success of a study using a simulation procedure it's important to have a well-defined approach. The phase sequence of a simulation study is subjective and several authors have different methodologies (Law 2009; Sargent 2013; Porta Nova 2008; Banks et al. 2014). Nevertheless, usually a simulation procedure includes the following phases

1) **F**ormulate the problem; 2) Define goals and create a overall project planning; 3) Gather data and conceptualize the model; 4) Validate the conceptual model; 5) Program and verify the model; 6) Validate the programmed model; 7) Plan and analyze experiments; 8) Analyze the simulation results; 9) Study the implementation; 10) Document the procedure.

2.4 Published Simulation Cases

Seen as a powerful tool to analyze complex stochastic systems, simulation has been used in several areas including health, marketing and in the military sector. Numerous successful cases of applications using simulation techniques applied to real problems prove its efficiency (Negahban & Smith 2014).

Schro et al. (2014) focused their analysis in two terminals of the Port of Rotterdam, which will help harbor authorities to investigate possible solutions to transport containers between the two terminals. A discrete simulation based on events model was developed, which simulates the system of both terminals and also incorporates the modeling of the traffic. Three different demand scenarios were analyzed (low, medium or high growth) for the transport of containers until the year 2030. This allowed to identify which performance indicators affect more the system operation, as well as to evaluate different operational aspects.

The study case developed by Lakshmanan (2014) is the most similar to the problem considered in this project. The aim of this study is to identify key bottlenecks along the supply chain and to recommend inventory levels optimized for the raw materials, semi-finished and finished products, taking into account the adjacent risks of demand and supply. The study analyze the effects of logistic's stability, as well as the long-term impacts of a closure of a critical supplier in the *Eastman* supply chain. Lakshmanan applied the discrete event simulation to analyze the problem. The creation of the simulation model helped to quantify the trade-off between various levels of inventory and the desired service levels. Various scenarios were also tested to study the long-term effects of a supply disruption and to define the level of inventory required to cover that risk.

3 Simulation Model development

3.1 Problem formulation

The system simulates *Recipharm*'s warehouse internal operations, from the receipt of raw materials to its shipping as a finished product. Given the large number of different products manufactured and stored in these facilities, and in order to simplify the analysis of the system in question, it was chosen a product that has a significant importance regarding to the storage

space required. This product is an anthelmintic[1], which taking into account its high demand and volume of merchandise, makes it a product of relevance in relation to the total locations which occupies in the warehouse, justifying this analysis. Since the product has a high number of raw materials, in order to simplify its analysis, it was decided that the only raw material to be taken into account would be the active substance (*Active Pharmaceutical Ingredient* (API)). Another component considered in this analysis are the flasks used in the product packaging, since they also have impact in terms of occupied locations in the warehouse.

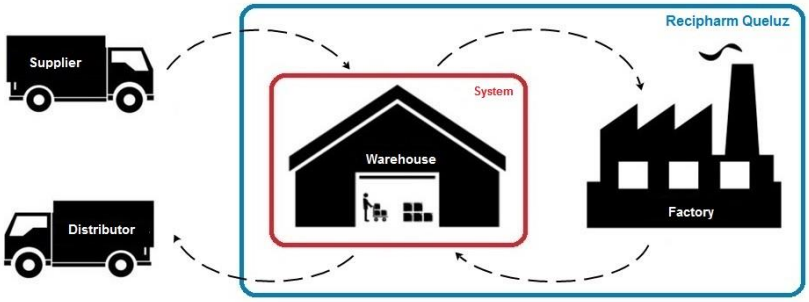

Figure 1 - System in study.

3.2 Gathering and analysis of relevant data

The warehouse under study operates Monday through Friday from 08:00h to 00:30h. However, the reception and sampling activities work in a shorter period than the rest of the warehouse, since they only work from 08:00h to 16:30h. On the other hand, the plant produces 24 hours a day, 7 days a week, as well as the activities that send the raw materials to the factory. The only factory section that also features a smaller schedule is the raw material's quality control room, since it operates only from Monday to Friday from 08:00h to 16:30h, and the quality control (QC) of finished products (FP), which operates in the same days but from 08:00h to 00:30h.

The API has a fixed amount per order of 6,000kg. After analyzing the book logs it was assumed that each API reception always occupies 35 locations equally.

The process of acquisition of Lusomedicamenta by Recipharm made the gathering data phase more difficult. However, it was possible to verify that the average between each arrival of the API to the warehouse is approximately 33 days. It was also possible to verify that the API was growing indefinitely until it reached its maximum capacity (300 locations) consequently congesting the entry of new API arrivals in the warehouse. Therefore, the team responsible for managing the warehouse stock level have decided to stop, regularly, the arrival of raw materials. This factor reflects the great variability in the system. That said, it was decided to adjust the timing of the API arrival to the warehouse in order to balance the system. The necessary calculations were made to avoid the congestion of the system and to ensure that the factory orders continue to be satisfied. This way, the API arrives to the warehouse every 57,000 minutes (roughly 40 days).

[1] A class of drugs used in the treatment of various parasitic diseases.

Flasks present no specification in the ordering process, but are received in 2,800 flasks pallets with the respective adjustment. 61 time intervals were analyzed from 2013, between each flasks reception. That said, a statistical distribution of the sample data was adjusted. This adjustment is based in the appointments of the curricular unit of simulation of processes and operations (Arantes 2014). It was concluded that the time between each flasks reception is approximately 14 days (20 160 minutes).

As already mentioned, the API received, and before its storage, must pass through the sample area. The sampling area has some physical limitations: it may only analyze a pallet at a time and operates only one worker. When analyzing the last 600 records of the sampling room logbook it was concluded that only 25% of the operating time of this section is used to analyze the API, the remaining time is used with other products.

With the help of the *Recipharm's* head of the quality control room, it was made an analysis of some data regarding the time needed to approve the use of the API, the flasks and the Finished Product (I), which allowed coming to the following values:

- API: For each lot of 6,000 kg of API, 75 hours are required.
- Flasks: For this procedure, are necessary 7:30h to analyze 27 pallets of flasks.
- Finished product: Analyzing the last year the records of, it was possible to verify that are required 12 hours (per pallet) to approve the dispatch of the finished product.

After analyzing the different operations needed in the production line it was possible to verify that usually are taken off the shelves 4 locations of API and 9 locations of flasks to produce a standard batch of the finished product. Afterwards are necessary 5 locations in the finished product shelf to store a full production batch. Additionally, it is possible to conclude that in a majority of the cases (82.5%) are ordered two batches to production, and in the remaining cases (17.5%) is requested only one lot. That said, a statistical distribution of the sample data was adjusted, similar to what was done with the entry fee of the flasks. Note that the adjustment test is based on the appointments of the simulation processes and operations course unit (Arantes 2014). The adjustment test concluded that every 6.5 days (9,360 minutes) the plant emits a manufacturing order.

According to the head of the warehouse, the limits for the components are as follows:

- API – 300 locations
- Flasks – 200 locations
- Finished product – 230 locations

Table 1 - Characterization of time of the studied activities.

Activities	Entity	Type	Measurements (minutes)		
			Minimum	Expectable	Maximum
Reception and verification	Flasks (for 27 pallets)	Triangular	9	13	20
	API (for 35 pallets)	Triangular	20	27	45
Entry in the system and labeling	Flasks (for 27 pallets)	Triangular	24	32	60
	API (for 35 pallets)	Triangular	60	75	115
Switching to plastic pallet	API (for 35 pallets)	Triangular	180	200	400
Sampling room	API (for 35 pallets)	Constant	1,575		
Changing to standard pallet	API (for 35 pallets)	Triangular	180	200	400
Storage	Flasks (for 27 pallets)	Triangular	81	135	270
	API (for 35 pallets)	Triangular	105	175	350
Quality control	Flasks (for 27 pallets)	Constant	450		
	API (for 35 pallets)	Constant	4,500		
Shipment to factory	Finished Product (per standard lot)	Triangular	40	60	90
Manufacture	Finished Product (per standard lot)	Triangular	5,340	6,300	7,260
Reception at factory	Finished Product (for pallet)	Triangular	1	2	3
Packing in vitafilm	Finished Product (for pallet)	Triangular	2	3	4
Storage	Finished Product (for pallet)	Triangular	1	2	3
Quality control	Finished Product (for pallet)	Constant	720		
Dispatch	Finished Product (for pallet)	Triangular	3	5	18

The model was validated, this aims to analyze whether the values resulting from the developed simulation model are framed with reality, or if there is any congestion in the model. This section also includes the stabilization of the system by setting the warm-up time, the simulation time and the number of runs to consider. The warm up is the time interval in which the software does not record the results, it´s the interval that it is necessary to stabilize the model for later to collect consistent results. From what has been stated above, given the wide variability that the system presents and although the raw material shelves are an aspect that is important to emphasize, only the following performance measures are considered:

- Average time in the system;
- Utilization rate of the final product's quality control resource;
- Average waiting time in the queue prior to the quality control of the finished product;
- Utilization rate of the sampling room resource;
- Utilization rate of the final product's shelves.

To define an adequate warm up period it's necessary that all performance measures are stable. By reading the charts it's clear that only from the 18th month the average system time begins to stabilize. It is concluded therefore that the warm up period to consider is 18 months.

By reading the charts it is possible to verify that, despite the evolution of the resource utilization rate is stable as early as 3 months, only after 24 months all performance measures are stabilized. Accordingly, the time considered in the simulation is 24 months.

The reading of the results shows that the average time spent in the system is the performance measure that has more variability, given the high number of runs recommended. Therefore, it is concluded that 42 is the number of runs more appropriate for the model.

3.3 – Simulation Model

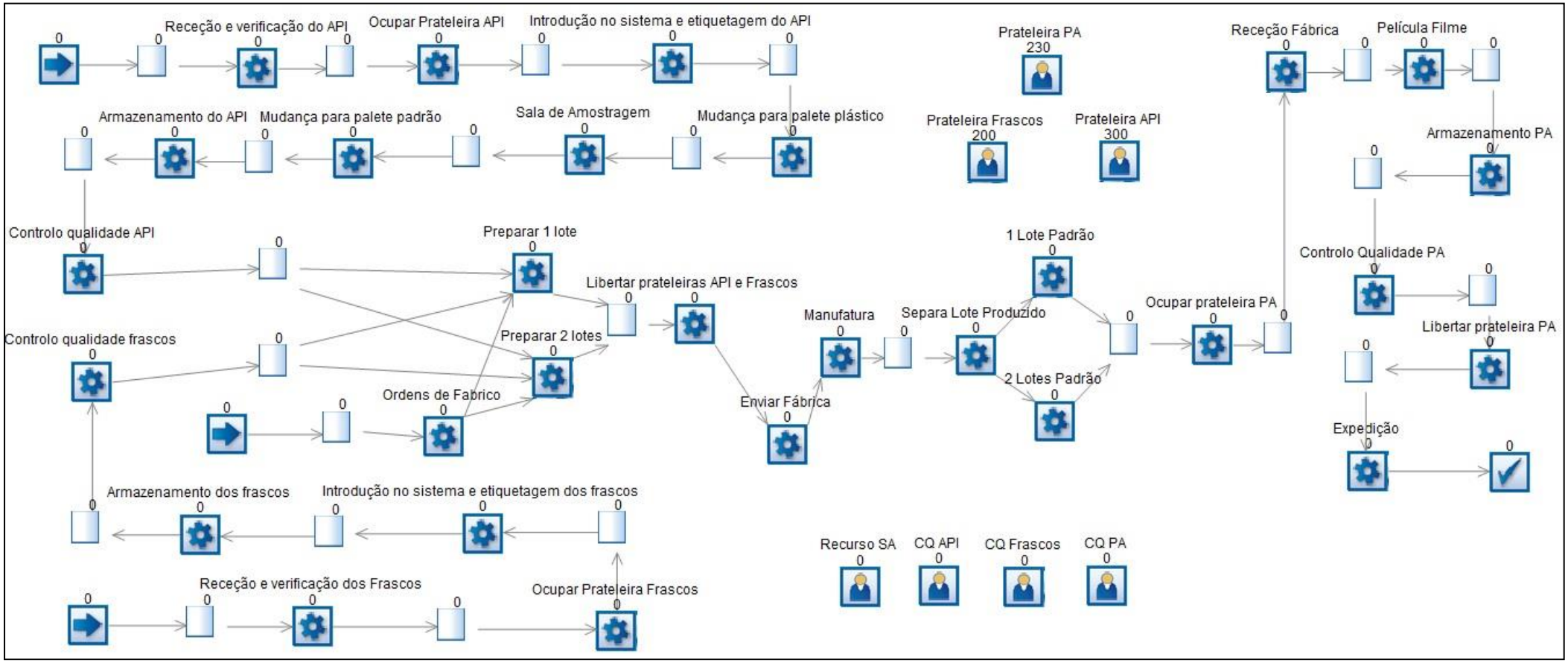

Figure 2 - Simulation model developed in SIMUL8.

3.4 Experiences and Discussion of the Results

Three experiments were conducted. To make these experiences some inputs from the model were changed in order to reduce the average time in the system, that is, the average time since the arrival of a manufacturing order to its dispatch as a finished product, since it is the performance measure directly related to the demand satisfaction.

Table 2 - Summary of parameter settings in each experiment.

Parameters	Experience 1	Experience 2	Experience 3
Simulation time	24 months	24 months	24 months
Warm up	18 months	18 months	18 months
Nº *runs*	42	42	42
Nº of manufacturing lines	1; 2 and 3	1	1
Nº of FP QC resources	1	1	1; 2 and 3
Nº of Sampling Room features	0.25	0.25; 0.50; 0.75 and 1	0.25

Table 3 - Summary of the results of the three experiments.

	Experience 1			Experience 2				Experience 3		
	Nº of manufacturing lines			Availability of resource at the SR				Nº of FP QC resources		
Performance measure description	**1**	**2**	**3**	**25%**	**50%**	**75%**	**100%**	**1**	**2**	**3**
Average time in system (minutes)	87,130.92	78,820.73	78,687.17	78,687.17	78,784.4	78,937.83	79,289.56	86,530.74	82,280.68	81,477.33
Average waiting time for sending raw materials to the factory (minutes)	15,332.32	116.07	15.52	15,332.32	16,362.98	16,502.39	16,812.08	15,332.32	15,333.28	15,332.93
Average waiting time for the sampling room (minutes)	10,880.34	10,880.34	10,880.34	10,880.34	4,954.92	2,938.92	2,049.78	10,880.34	10,880.34	10,880.34
Average waiting time for the FP QC (minutes)	6,174.12	18,991.16	19,496.05	19,496.05	18,871.84	18,871.68	18,897.77	6,161.89	1,793.66	979.88

Experience 1

It is perceptible the impact it has on the waiting time in the delivery of raw material to the factory the fact that of adding one or two manufacturing lines. Analyzing the data, it is possible to obtain a reduction of 9.5% in the average time in the system and of 99.2% (a reduction of 10.6 days) on the average waiting time for sending raw materials to the factory. Regarding the reduction of average time in the system it is possible to conclude that one gets a reduction of 9.5%. Another conclusion from this experience is that the implementation of a third production line does not have an impact as significant as the difference from one to two production lines.

Experience 2

This analysis also shows that the greatest variation that exists is when the resource dedicates 50% of its working hours in the API sampling, reducing the average waiting time in approximately 4.1 days.

Experience 3

This analysis shows that the implementation of a second feature in the product quality control activity expresses a reduction of approximately 2.9 days in the average time in the system,

which corresponds to a variation of -4.91%. However, the reduction achieved with the implementation of a third element is not so significant.

Once completed the one-dimensional analysis performed for each of the experiments, it was decided to perform a multidimensional analysis in order to present intermediate solutions. This comparative analysis allows us to take another interesting conclusion. The implementation of a second production line in the factory showed a reduction in the average time in system of about 6 days, in contrast to the reduction of only 4.4 days achieved with the configuration to maintain a single production line but increasing the number of resources in the FP QC room to 3 and the availability of the SR resource for 100%. Of the several solutions presented is possible to obtain a greater reduction in the average time in system by implementing a second manufacturing line, and by adding only one more resource to the FP QC room, with these proposals we will obtain a reduction of roughly 11.3 days, the equivalent to a reduction of 20.4% in time when compared to the current situation.

Conclusions

Recipharm is a multinational company, headquartered in Sweden, specialized in the production and development of pharmaceutical products. With the increasing demand for the products manufactured at the facility, and due to the physical constraints of the Queluz warehouse of *Recipharm*, considering that it´s not possible to expand its current area, arises the need to reformulate its operations to obtain a more efficient use of the space in storage, while maintaining the high service level. It is in this context that the present work was developed, aiming to improve the operations in the *Recipharm* warehouse.

This project was developed using the discrete event simulation procedure, using the SIMUL8 software as a tool capable of assisting the analysis of this study. During the development phase of the simulation model several difficulties were faced, as the fact that the realization of this study coincided with the acquisition of Lusomedicamenta by *Recipharm*. The change of managers and operational standards made the acquisition and validation of the data collected more difficult. Despite all the setbacks faced, it was possible to carry out this study and draw important conclusions.

The simulation model developed allowed to confirm the various bottlenecks that were previously identified, in queues in the occupation of the API, in the sampling room, in the sending of batches of production to the factory and at the FP quality control, as well as the charges for using the resources of the sampling room and the finished product quality control.

Through the experiments performed it was possible to conclude that with the implementation of a second production line it is possible to obtain a reduction of 9.5% (roughly 6 days) in the average time in system. In addition, the results show that the placement of a third production line doesn´t show significant reductions, registering a decrease of only 3.8 hours. Another interesting conclusion that could be drawn from the analysis of the results is that the number of resources in the finished product quality control activity is the parameter that has the most

impact in reducing the average time in system, in contrast with the variation of the parameter related to the availability of the sampling room.

After the one-dimensional experiments were completed, it was decided to conduct a multidimensional analysis in order to present intermediate solutions. Thus, through one of these solutions, it can be concluded that implementing a second manufacturing line and adding another finished product quality control resource has a significant impact in the average time in the system, reducing it by 11.3 days, which represents a reduction of roughly 20.4% when compared to the current situation.

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