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RELAZIONE PER IL CONSEGUIMENTO DELLA LAUREA MAGISTRALE IN INGEGNERIA GESTIONALE

INCREASING THE AVAILABILITY OF A MANUFACTURING CELL THROUGH OPERATIONAL IMPROVEMENTS

SINTESI

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Sommario

Sterifill, il prodotto considerato in questo elaborato, è prodotto su una linea di produzione che ha al momento una Overall Equipment Effectiveness (OEE) pari a 55% e la domanda del prodotto nei prossimi 5 anni prevede un aumento superiore al 35%.

Lo scopo di questo progetto è quindi quello di utilizzare simulazioni software per testare scenari differenti. Per fare ciò è stata inizialmente svolta una accurata analisi dei dati, ponendo particolare attenzione alle informazioni riguardanti i guasti sulla linea.

Successivamente è stata creata una value stream map, per identificare le maggiori perdite all'interno del processo.

Una volta terminata la creazione e validazione della simulazione as-is, differenti scenari sono stati implementati con lo scopo di identificare le proposte migliori per l'azienda, valutando l'incremento in termini di produttività e disponibilità della linea e calcolando il valore attuale netto per ognuno di essi.

I risultati ottenuti mostrano la possibilità per l'azienda di apportare modifiche alla linea produttiva, raggiungendo quindi il throughput necessario per soddisfare la domanda futura.

Abstract

Sterifill, the product considered in this thesis, is produced on a line that is currently running at an OEE of 55% and the demand forecast over the next 5 to is showing an increase higher than 35% for this product.

The aim of this project was to use simulation to test different scenarios to increase the throughput and the availability of the manufacturing line. To reach the goal a deep data analysis has been necessary, with a special focus on the breakdowns' information.

Then, a creation of a value stream mapping was conducted to better identify the major wastes in the process.

Once the as-is simulated model has been created and validates, different scenarios have been tested to identify the best solution for the company.

The results obtained highlighted the possibility for the company to apport modification to the production plan with an increase in the availability and in the throughput of the line, reaching the request demand in the following years.

1. Introduction

A smooth flow of materials through the operations and supply chain, with minimal disruption or delay, is what manufacturing organizations strive for. In the pharmaceutical and medical industries, this is often achieved using cellular manufacturing systems. Cellular manufacturing allows high levels of material flow through the production processes among other benefits such as improved work-in-progress levels, space utilization decreases, lead time reduction, productivity improvement, quality improvement, enhanced flexibility, and visibility increase.

However, a disadvantage of using a cellular manufacturing system is that a single machine failure might shut down the entire line. A manufacturing organization would be more successful in understanding and improving its operations by first identifying the crucial processes that have an impact on the production capacity, quality, and delivery. Once these processes have been identified, the creation of a process map will help comprehend their key characteristics and produce usable analytical data for conducting data analysis.

1.1. About The Company

BD (Beckton Dickinson) is a multinational company operating in the medical industry that manufactures and sells medical devices, instrument systems and reagents. In particular, BD Swindon is a plant situated in the UK and it is part of BD Medical Pharmaceutical System Business Unit, delegated to the development and manufacture of plastic drug delivery systems and safety devices, especially the moulding and assembly processes.

1.2. Aim And Objectives

One of the main medical devices produced by the site, Sterifill, is facing a massive increase in its demand so the company needs to increase the number of products produced per year. As visible in Figure 1, BD expects the demand to increase by more than 35% in the next 5 years.

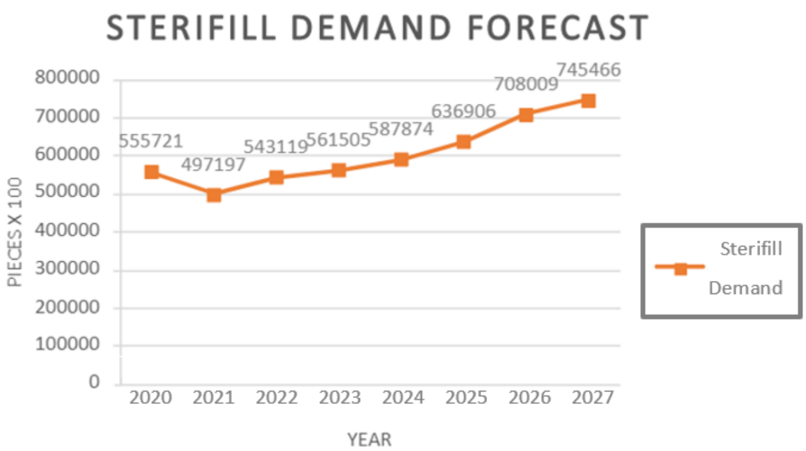

Figure 1- Sterifill Demand Forecast

The aim of the project was to increase the actual throughput of the line, focusing on actions to increase the availability and consequently the Overall Equipment Effectiveness (OEE), that is currently below 55% (data provided by the company). To reach that goal, the project has been deployed in 7 phases, and to each of them an objective has been allocated.

1.3. Methodology

As said previously, the project has been divided in 7 phases and an objective has been allocated to each of it, to better proceed during the entire conduction of the project, as shown in Table 1.

STEP	OBJECTIVES
Understanding of the problem	Formulation of aim and objectives
Study of the current state of art	Literature review formulation
Collection and analysis of data	Breakdowns analysis and files creation
Construction of the as-is simulation model	As-is WITNESS model construction
Analysis of the results	Validation and verification of the model
Formulation and implementation of new scenarios	Creation of a scenarios list and to-be WITNESS models
Strategy proposal	Proposal of a strategy

Table 1- Phases and Objectives

The first step consisted in understanding the problem faced by the company and the main reasons behind that. Then it was necessary to analyse how the problem was solved in the past and to study the literature review related to the industry and the simulations. After a deep understanding of the situation and of the possible solutions that can be used to improve the current state, it was crucial to collect the data on site, directly from the production line. This was done with regular weekly visit to the plant located in Swindon. A first simulation was carried out on WITNESS software, based on the requirements pointed out by the company, on the data collected and analysed and on the current production line. After a study of the emerged results and an examination of the possible improvements, 4 different scenarios were implemented and tested in the software and the results were analysed in terms of throughput and availability increase. Lastly, a strategy was formulated and proposed to the company to help them to increase their OEE with a consequent increase in the production.

2. Data Collection

The accuracy of the simulation throughout all phases of the project strongly depends on the data reliability, thus, several different strategies of data collection have been considered. These strategies included interviews with operators and managers, manual data collection, secondary data from databases, and observation of the clean room. Data collected was then analysed to understand the system and used as inputs to the simulation model.

The analysed data revealed that the manufacturing cells have set-up times only on the moulding machines, which are running 24 hours per day. Every set-up has a duration of 3 hours, which it occurs after either a breakdown, a restart due to change of die on the moulding machine, or a stoppage that lasts more than 15 minutes. Data used for the simulation included breakdowns (characterized by MTBF and MTTR), cycle time, scrap rate, set-up time, buffers and conveyor capacity, operators' and technicians' shifts. Assumptions made for the simulation includes the interarrival times for parts are immediate, parts supplied by external suppliers are always available, the technician is always available, but the MTTR includes the waiting time necessary for them to arrive in the cleanroom, one operator is always allocated to the packaging area, one operator is always allocated to the quality check station, the moulding process is simulated as a single process, each machine process 2 parts per time, and the non-adding value machines have been eliminated (this is to reduce complexity in the model). All the model assumptions have been verified with management prior to their inclusion in the model.

3. Value Stream Mapping

The map has been used to better investigate the performances of the main steps that compose the manufacturing process, displaying the important indicators of them. This tool is the one that better permits to show the necessary information regarding the production flow and highlight the possible areas of improvement. The information in Figure 2 regards cycle-times, number of machines, WIP inside the machines, the eventual necessity of an operator and other characteristics, depending on the singular process. Those indicators have then been used for the construction of the as-is simulation.

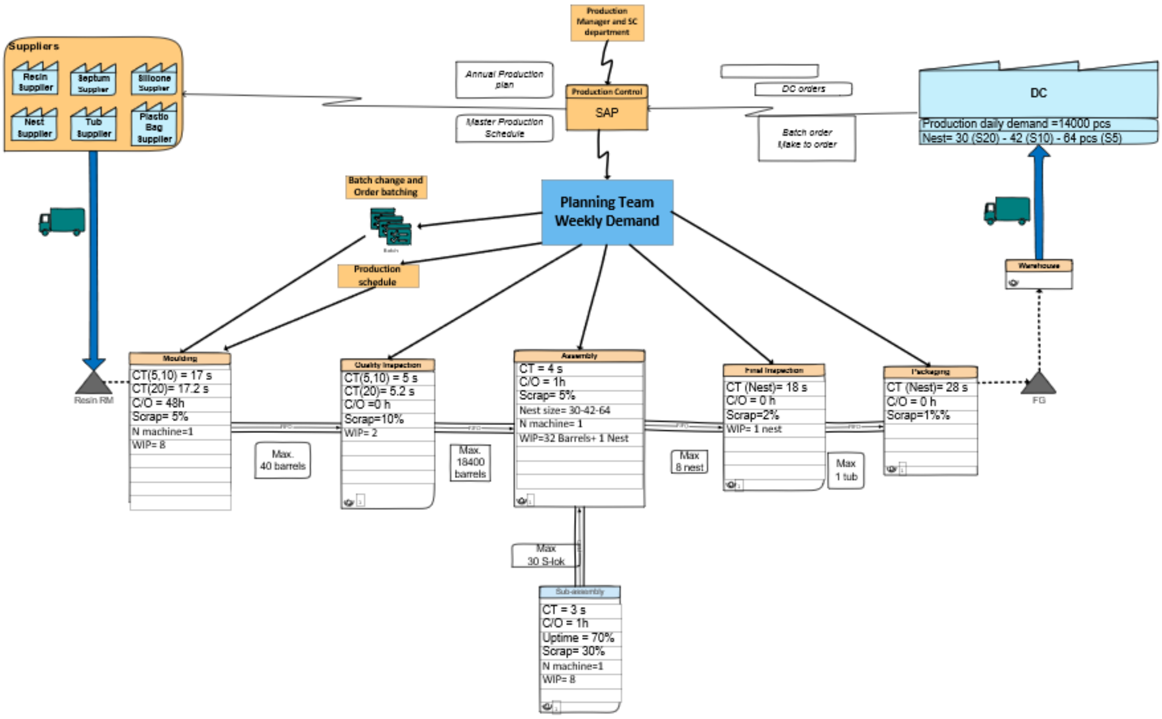

Figure 2- Value Stream Map

4. AS-IS Simulation

The architecture of the real model has been created based on the layout map and the VSM showed in Figure 3.

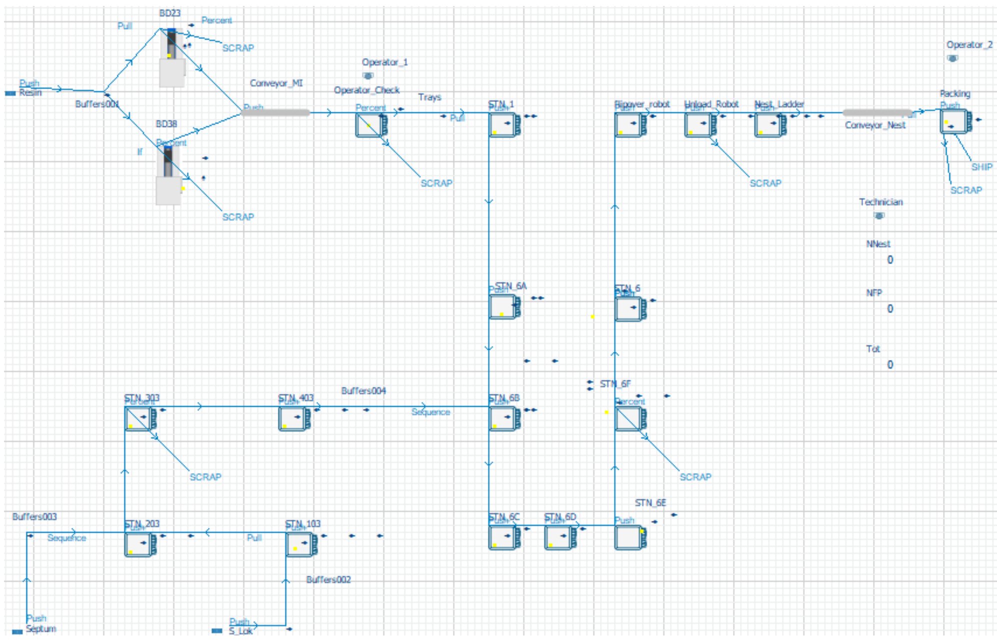

Figure 3- As-Is Simulated Model

The model has been created based on the current layout of the Sterifill production line, recreating some of the machines, conveyors, buffers and operators that are available in the cleanroom. It is important to keep in mind that every simulated model, even the best one, is not reflecting 100% the real one. Because of this, it has been necessary to make some assumptions while creating the model, to better recreate the real process.

4.1. Verification

Each single machine has been tested individually, ensuring that the simulated element was behaving as the real one. After the verification of each entity, a verification of the entire model has been conducted, analysing the behaviour of the simulation in terms of breakdowns, set-ups, flow of the parts, etc.

4.2. Validation

KPIs data have been requested from the company and compared with the simulated outcomes. Table 2 contains KPI ranges and not specific values because those intervals consider the fact that there is a fluctuation in the production. These ranges were provided by and agreed with the management of the company, The simulated data needs to fall within those ranges, for the model to be validated. The model has been run 30 times, each time for a length of one year. The number of repetitions has been decided continuing to run the simulation until the variation of the results was low enough to consider the obtained outcomes reliable. All the simulated data were inside the validation ranges, so the model has been considered valid and so was used for to-be scenarios.

KPI	AVERAGE SIMULATED RESULTS	VALUE RANGE	VALIDATE ?
Sterifill 20 Daily Output [p/day]	14673	13.500/ 15.500	V
Sterifill 10 Daily Output [p/day]	15750	14.000/ 16.000	V
Sterifill 5 Daily Output [p/day]	16301	14.500/ 16.500	V
Total Scrap Moulding [%]	11.2%	[10.00-15.00]	V
Total Scrap Assembly [%]	5.7%	[5.0- 6.0]	V
Downtime Moulding Daily Avr. [min/day]	297	[240-300]	V
Downtime Assembly Daily Avr. [min/day]	421	[390- 450]	V

Table 2- Validation Test Data

All the simulated data were inside the validation ranges, so the model has been considered validate ad it has been possible to use it for the implementation of the to-be simulations with the different scenarios.

5. TO-BE Simulation

The as-is simulation, and the analysis of the cycle-times of the different stations, highlighted that the moulding process is the bottleneck of entire the process. The problem has been identified in the manual check because the operator needs a higher time compared to the barrel moulding process. Moreover, the quality of this quality check is low, due to the possibility of human errors. Every time that the moulding machine stops for more than 15 minutes it is necessary to ramp up the process again, with a decrease of moulded barrel and a decrease in terms of availability, and hence throughput. Based on the as-is simulation analysis, direct observations of the cleanroom, interviews conducted with the operators and technicians, and suggestions of the management team, different scenarios have been formulated. The scenarios focus on increasing the availability and the throughput of the manufacturing cells. The decision to implement one scenario over another was done by comparing those two key performance indicators as well as factoring in gross margin contribution, and all associated costs to calculate the Net Present Value of each proposed solution to assess its feasibility.

The possibility to analyse different scenarios based on the as-is model was a paramount factor for the company because it gave them the possibility to evaluate the impact of different actions in terms of throughput rise and availability increase. The simulation permitted them to do this without massive investments and expenditures and also avoiding line stoppages and alterations of the cells. The final analysis took in consideration 4 scenarios:

- **Scenario 1:** Substitute the manual check in the moulding area with a camera check.
- **Scenario 2:** Use both moulding machines at the same time, and substitute the manual check in the moulding area with a camera check
- **Scenario 3:** Employ a full-time technician in the clean room
- **Scenario 4:** Increase the buffer capacity for moulding

Those scenarios have been tested, and the results have been analysed. The results focus more on the throughout increase rather than on the availability increase because the company preferred to obtain information regarding this factor. All of those options tried to increase directly or indirectly the availability of the line, that is currently equal to 67.2%.

It was important to understand the efforts required to implement each scenario on the real production line, considering the costs related to it, not only in terms of money. At the same time the possible benefits coming from the new production process needed to be discover.

To give a good overview of how the scenarios have been evaluated, the process will be explained below taking into consideration the first scenario. The methodology descripted below is has been applied to each scenario.

Analysis of the scenario

After an analysis of the impact of the changes coming from the first scenario, it has been possible to identify 5 major benefits and 5 major efforts coming from the new scenario that are presented in Table 3.

BENEFITS	EFFORTS
Throughput and availability increases	Purchase of new station
Less variability in the process	Breakdowns increase
Elimination of operators' costs and salary	Stoppage of the line
Errors decrease	Company image issue
Set-up decrease	Operators' relocation

Table 3- Scenario 1: Benefits-Efforts

The first benefit is the throughput increase, and the quantification of the rise is shown in Table 4.

PRODUCT VARIANT	OLD THROUGHPUT	NEW THROUGHPUT	T. % INCREASE
Sterifill 20 ml	14673	15504	5.66%
Sterifill 10 ml	15750	16862	7.06%
Sterifill 5 ml	16301	17514	7.44%

Tabella 4- Scenario 1: Throughput Increase

It is possible to notice from Table 4 an increment that could give the possibility to the company to get closer to the productivity request. Also having an automated machine permits to decrease the variation of the station. This can be possible due to the fact that the operator check's duration varies every time, depending on the employee performance, but with the adoption of an automated mechanism the cycle-time is the same for every repetition.

It was important to consider the expenditure necessary to the purchase of the new camera and all the related costs on the new machine and at the same time to evaluate the savings coming from this option. In the table below a calculation of the Net Present Value has been proposed.

Cost Item	Year 0	Year 1	Year 2	Year 3	Year 4
Gross Margin Contribution	104,536	241,907	241,907	241,907	241,907
Operators Cost	162,702	162,702	162,702	162,702	162,702
Total Saving	**267,238**	**404,609**	**404,609**	**404,609**	**404,609**
Purchase Camera	- 123,000				
Oerators and Technician Course	- 8,500				
SW Development	- 50,000				
Installation and test	- 24,000				
Mantainance	- 11,000	- 11,000	- 11,000	- 11,000	- 11,000
SW Engineer	- 12,000	- 6,000	- 6,000	- 6,000	- 6,000
Total Cost	**- 228,500**	**- 17,000**	**- 17,000**	**- 17,000**	**- 17,000**
Delta	**38,738**	**387,609**	**387,609**	**387,609**	**387,609**
NPV	**1,381,845**				

Figure 4- Scenario 1: Net Present Value

The elimination of the manual check gives the possibility to remove the operators' salary and costs, that are equal to 53,234.00£ per year, per single operator. Considering that Sterifill production is a continuous one, and that the company runs shifts of 8 hours, the final saving for the company is equal to 162,702.00£ per year. This estimation is based on the current salaries that the company is paying to the operators in the cleanroom and the additional expenditures that the company has for each person, such as pension compensation and insurance. However, the reputation of the company can be impacted by the operators' dismissal and in this case a relocation of the workforce may be necessary. Lastly, the new scenario permits to decrease the human error coming from a poor visual inspection.

The Gross Margin Contribution (GMC) has been calculated using the GMCu (provided by BD) considering a timespan on 5 years, and assuming that all the additional products can be sold during it. In the GMC row in Figure 4 the estimated value is illustrated.

The line would need to stop 2 weeks to instal and check the new machine, and this is the reason why the GMC is lower in year0. Ultimately, the new machine will have breakdowns and they will impact on the availability of the line. However, it is important to consider that the decrease in the stoppages of the moulding machine caused by the fact that the conveyor between it and the operator is full, decrease the set-up time and the set-up number of the moulding process. For this reason, the availability of the line obtains an overall increase of 7.4%. The Net Present Value (NPV) predicted for this scenario is 1,381,845.00£.

5.1. Scenario Comparison

A comparison of the different scenarios has been made, considering the economic costs and the throughput increases related to each one. The table below (Table 5) presents the different results obtained.

	S1	S2	S3	S4
Sterifill 20 ml (t. increase)	5.66%	13.13%	8.14%	2.01%
Sterifill 10ml (t. increase)	7.06%	14.47%	8.04%	1.33%
Sterifill 5ml (t. increase)	7.44%	14.97%	8.31%	1.71%
Average t. increase	6.72%	14.19%	8.16%	1.68%
NPV (£)	1,381,845	2,575,957	538,326	279,441
Availability increase	7.4%	12.6%	3.7%	0%

Table 5- Throughput and Availability Increases and NPV Comparison

The average t. increase is the average of the throughput increase of the 3 different variants for each scenario. From the data obtained, the best scenario seems to be second one, both in terms of availability increase and NVP. After a presentation of those results to the management team, a simulation with the merge of scenario 2 and 4 has been requested, considering the eventual costs of the future implementation of those options in the real plant and the budget that the product obtained from the board to increase the productivity. Based on those results, a final proposed scenario has been implemented in the simulation software and the results in Table 6 and Figure 5 has been obtained.

PRODUCT	OLD THROUGHPUT	NEW THROUGHPUT	T. % INCREASE
Sterifill 20 ml	14673	16836	14.74%
Sterifill 10 ml	15750	18134	15.13%
Sterifill 5 ml	16301	18848	15.62%

Table 6- Final Scenario Throughput Increase

Cost Item	Year 0	Year 1	Year 2	Year 3	Year 4
Gross Margin Contribution	408,530	545,901	545,901	545,901	545,901
Operators Cost	162,702	162,702	162,702	162,702	162,702
Total Saving	**571,232**	**708,603**	**708,603**	**708,603**	**708,603**
Rack Cost	- 2,378				
Purchase Camera	- 123,000				
Oerators and Technician Course	- 8,500				
SW Development	- 50,000				
Installation and test	- 24,000				
Mantainance	- 11,000	- 11,000	- 11,000	- 11,000	- 11,000
SW Engineer	- 12,000	- 6,000	- 6,000	- 6,000	- 6,000
Total Cost	**- 230,878**	**- 17,000**	**- 17,000**	**- 17,000**	**- 17,000**
Delta	**340,354**	**691,603**	**691,603**	**691,603**	**691,603**
NPV	**2,736,831**				

Figura 5- Proposed Scenario: Net Present Value

The final NPV obtainable applying the two scenarios simultaneously could give the possibility to the company to obtain a final NPV of 2,736,831.00£ in the next 5 years, this means that the company not only will be able to cover entirely the costs, but also to obtain a profit and satisfy the clients' request. it has been possible to calculate an availability increase equal to

13.1%, obtaining an overall availability indicator of 76.1%. A OEE of 62.2% has been reached, gaining an increase on it of 12.2% from the initial one that was 55.0%

6. Recommendation

As shown by the data in Table 6, the scenario that includes the substitution of the manual check with a camera check, the increase of the moulding barrel buffer and that utilises the 2 moulding machines simultaneously seems to be the best cost-effective way to increase the production on the line. The new average yearly production, calculated with the average of the throughput obtained, would reach 6547,857 pieces per year, obtaining an increase of 863,104 pieces per year. This 15.18% is a good start, that could provide a coverage for the forecast demand increase of sequent year. However, the predicted 2026 demand (illustrated in Figure 1) is higher than the throughput obtained for the final scenario, so the company should undertake additional actions in the future years. The third scenario has not been selected but other studies regarding the breakdowns should be conducted, aiming to decrease their frequency and also their duration. Additional improvements can be done, not directly related with the objectives of this work but still beneficial for the company, such us a better breakdown data reports and analysis and also an analysis of the scraps.

7. Conclusion

The objective set by the company was focused on increasing the throughput level of Sterifill to keep up with the increase of the product demand. To approach the project the main steps were sets and faced one per time. After an intense study of the work of arts, a data collection and analysis phase has been carried out. The process has then been mapped to better evaluate the actual performance of the production line, with a deeper analysis of the breakdowns of the line. Then the process has been modelled on WITNESS software and been validated and verified. Several scenarios have been proposed and four of them have been tested, modifying the simulated model. This was done to predict the outcomes of the different changes in the production line that BD could implement, without the need of a physical modification of the cells. With a final evaluation of the obtained results the different scenarios have been analysed, finding best combination of those to increment the throughput of the line, with input coming from Senior Management of the company and from direct observations of the cells. To conclude, it is possible to say that a first suggestion of modification of the shop floor has been proposed to the company to keep up with the increasing demand in the next few years and to gain a profit, and further study has been defined, providing the company additional information to improve the current production.