Public Summary of Thesis B-IEM, Lennart Hendriksen s2834324

Improving the production at Company X by simulation

Introduction

This thesis digs into the production process of the products of Company X that contain Element F. Company X produces all kinds of products, especially for different brands. It is very valuable for Company X to be able to improve the production process of those products that contain Element F. This is also the goal of the thesis, to see where the production of products with Element F can be improved. A discrete-event simulation is used to replicate the production of Company X and to see where the production can be improved. The simulation programme used in this research is Siemens Tecnomatix Plant Simulation 16.1.

General production introduction

At the start of the production, Product A enters the production site of Company X. After entering the production, Product A is processed by two processes. After doing so, the raw product has become an Element. The two processes that process Product A both consist of multiple machines. These settings can be manually adjusted by Company X, resulting in different percentages of elements retrieved from Product A. The Element is thereafter, depending on their aspects, put into certain silos. From the silos, the Element enters a production line. Which production line is entered depends on the final product that needs to be made. Company X produces different products for different brands. All products contain either Element G, Element H or Element F.

As there has been an increase in the demand for products containing Element F, there is an increased profit margin. The sales department of Company X had found out that there is more demand than what Company X and her competitors can produce. Company X has in the department which this thesis is about, 9 production lines. Each of these production lines can produce products with either Element G, Element H or Element F, depending on their design and specifications. In total, there are 5 production lines which can produce products containing Element F.

Each production line currently has a certain set of slots in which it produces products. For example, Production Line 1 and Production Line 2 only produce during the weekdays. Production line 3 only produces on Tuesday, Wednesday, Thursday and Friday in the current situation. Production line 1 and 2 only produce on weekdays, as that is when the employees of that department are present. Production line 3 only operates on Tuesday to Friday to due to the silo prioritisation and the inflow of Product A. Products that have been created on Production Line 3 are directly shipped due to the characteristics of that production line. As Company X follows the Make to Order strategy, they do not really own a warehouse. For those orders that need to be stored, Company X uses the storage of a logistics company nearby.

Core Problem

As mentioned in the introduction, the sales department found out that there is a highly increased demand for products containing Element F. In the past year 23 Units (unit for confidentiality) of products containing Element F were produced. However, the goal had been set by Company X to produce 34 Units of products containing Element F on a yearly basis. This results in a gap of 47.8%. However, the company did not have a clear view of what prevents them from producing more. Additionally, the company also did not know how to produce more, with the best trade-off with regards to the investment.

As mentioned in the introduction, an improvement of the Element F-related production lines will generate a lot of money for Company X. This is due to the increased demand and the supply that cannot keep up with the demand. Hence, the core problem of Company X is that they cannot cope with the demand, and cannot reach the set goal of an increase of 47.8% on a yearly basis.

Research Design

After spending multiple days at Company X, there had been made multiple research questions, which together answer the main research question. The main research question is as follows: "How to increase the production by 47.8% while preventing the occurrence of bottlenecks at Company X". To answer this question, four sub-questions have been made. Some of those also have sub-questions on their own to answer the sub-questions itself. The questions are as follows:

1. What is the current process and decision-making strategy in the production of products with Element F?

2. What type of bottleneck detection methods, focusing on production lines, are there in literature?

3. How can the current situation be best implemented in the simulation model?

4. What is the most beneficial solution to increase the production of products containing Element F?

Regarding the first question about the current process and decision-making strategy, a set of different data-gathering methods has been applied to gather the needed data. Firstly, ***unstructured interviews*** were conducted with the company supervisor, combined with private tours of the different departments of Company X. Secondly, the morning meetings were attended to get a better understanding of the current situation and the production process. This was also done get familiar with the employees throughout the different levels of the hierarchy. Lastly, all the available data was thoroughly analysed.

To answer the second sub-question, a systematic literature review was implemented, in which multiple databases have been conducted.

Scope of the research

Due to the 10-week length of the thesis, the scope of the research had to be narrowed down. Together with the company supervisor, and in consultation with the production manager the boundaries and simplifications of the research had been set. The general scope of this research starts at Product A being transported into the silos, and ends when the products with Element F have been created on the corresponding production line. The specific scope includes the three largest silos, three of the six production lines which can handle Element F and the route conflicts in the production.

There is a broad selection of possible routes which the Elements and Products can pass, depending on what is being produced. Due to the broad selection of possible routes, there are some routes that conflict with each other. This research looked into the routes that include Element F, and checked for route conflicts on those specific routes. Due to the time constraint, one of the two route conflicts has also been included into the simulation. As the scope was broadly discussed with the company supervisor and production manager before and during the research, we consider this to be a reliable research.

Literature review

The literature review consists of three pillars. These pillars were designed to build a basis of knowledge, whereafter it goes deeper where needed for this thesis and de accompanying research questions. Firstly, the literature review builds a broad foundation on bottlenecks. By solving the bottleneck, the production can be improved. This is because a bottleneck is “a point of congestion in a production system (such as an assembly line or a computer network) that stops or severely slows the system.”(Investopedia, 2023). Literature (Croft, 2024) explains that there are different types of bottlenecks, which are categorized as physical, technical and organizational bottlenecks. Besides this set of categories, there is another set of categories defined in literature. This regards the short-term bottlenecks and long-term bottlenecks. The short-term bottlenecks are “temporary and usually caused by employees on vacation or sick leave”, whilst long-term bottlenecks are “built into the manufacturing protocol and often related to inefficient equipment or processes”(Investopedia, 2023).

Secondly, the literature review deepens into bottlenecks, namely by reviewing the literature about bottleneck detection methods. This section of the literature suggests methods as the queue length method (Skoogh et al., 2023) and the waiting time method (Roser et al., 2001) which focus on the queue state. The bottleneck walk (Roser et al., 2014) which focusus on a distinction between upstream and downstream bottlenecks is also suggested. Then, a combination of bottleneck detection methods from Alzubi et al. (2019) is stated. They combine the waiting time method and the utilisation method. Last named method defines the bottleneck to be the resource or machine with the highest utlisation. All the mentioned bottleneck detection methods differ based on the available data and where the focus lies in the bottleneck detection. Due to the available data and focus of Company X, a combination of bottleneck detection methods is chosen. This is the same combination as applied by Alzubi et al. (2019). The waiting time method and utilisation method are chosen as this research also uses a discrete-event simulation as Alzubi et al. (2019) did.

Lastly, the literature review dives into the different production line optimisation methods. Even though the thesis mentions the Total Productive Maintenance, it finally chooses the Theory of Constraints as the production line optimisation.

Solution design

The solution design of the thesis consists of three parts. Firstly, a conceptual model has been created to function as the foundation of the model. The conceptual model is a “non-software description of the simulation model consisting of the objectives, inputs, outputs content assumptions”(Robinson (2004)). Inputs of the thesis are the arrival rate of Product A, the machine breakdown, Mean Time To Repair, Mean Time Before Failure and the shifts. Assumptions and simplifications of this thesis are the arrival rate distribution, infinite storage, processing times and the absence of employees. The output of the model is the throughput per line.

The Simulation model is the second part of the solution design. As the arrival rate of Product A is lower in the weekend than during weekdays, there are two source objects to simulate this. Two “shiftcalendar” objects regulate the operating times of the source objects that create Product A.

After being created, Product A moves to one of the three silos that are incorporated into the thesis and the simulation model. The prioritization is managed by a method, that moves Product A to a certain silo, depending on the day of the week and how full the silos are. After talks with employees of different departments, the code is written to replicate the reality as closely as possible. For these three silos, a buffer object is chosen to mimic the aspects of a silo.

Once one of the three production lines is available, the Product A moves from the corresponding silo to the corresponding production line. For the simulation, the three production lines that produce the most Products with Element F are within the scope of the thesis and implemented into the simulation. The production aspects of the three production lines are regulated by a method containing the code that also moves the Products with Element F towards the drain-objects once they are processed. While the simulation runs, there are two objects with code that gather all the needed date, which is immediately put into six different graphs.

The third part of the solution design is the experimental setup. This discusses the warmup-period, run length and the number of replications. The warm-up period was decided to not be necessary. This is because the silos were filled with the Element F before the simulation. The fill level was decided upon by taking the average level on which the silos were in reality at that day and time of the week. The average level was taken of the last 29 data points. More data points would have been chosen if Company X would not have had a major maintenance project which affected the fill levels. The run length of the simulation was chosen to be 30 days after consultation with the company supervisor. As the data was collected per shift, this resulted in 180 data points per KPI. The number of replications was set to 0 due to the minimal level of variability between replications. As the interarrival times of Product A were the only variability in the model, there was little to no difference between the replications. Hence, it was decided to keep the number of replications at 0.

Methods used for validation of the design

For this thesis, the white-box and black-box methods have been applied to the model. The white-box method is used as a verification method, whilst the black-box method is used as a validation method. As stated by Nidhra & Dondeti (2012), the white-box testing is used "for debugging a code, finding random typographical errors and uncovering incorrect programming assumptions". This testing was done in two steps. Firstly, the code was constantly debugged when adjustments were made to the model. Secondly, some parameters of the simulation were set to extreme levels to see if the model would return illogical values. Furthermore certain codes were added to the simulation model to make sure that infeasible situation take place. For example, code has been written which creates a message box if all silos are full. This would not directly have been visible with merely running the simulation. The black-box method has mainly been used with the company supervisor.

For the black-box testing, the tester should not have access to the software, as the testing focuses "solely on the outputs generated in response to selected inputs and execution conditions" (Nhidra & Dondeti, 2012). The black-box validation could be performed very well as the company supervisor has thorough knowledge on the production, but no access or knowledge of the software. In this way, the supervisor, the tester, could check if the output was realistic, without having access to the software.

Solution Sub-question 1

The first sub-question about the current process and decision-making strategy is answered by describing the aspects of each step of the production. This starts with mentioning the maximum production speed of the transportation of Product A into the silos. Then, the research shows why three of the production lines are included into the research. These were chosen as they account for more than 87% of the production of products containing Element F. In the current production, there are seven routes that can process Element F, of which two are conflicting with each other. Furthermore, the planning department chooses in which order and on which shifts all the products are being produced.

Solution Sub-question 2

The second sub-question is about the bottleneck detection methods in literature. It discusses that five bottleneck detection methods are found in literature. These are the queue length method, the waiting time method, the bottleneck walk, value stream mapping and the utilisation method. Of these bottleneck detection methods, the utilisation method, retrieved from Alzubi et al. (2019) is used in this research. That method states that the resource or machine with the highest utilisation is the bottleneck.

Solution Sub-question 3

Then, the question about how to implement the current situation into the simulation model is answered. First, the conceptual model has been made as a foundation for the simulation model. This was also done to check the aspects of the research with the company supervisor. Besides this, the production rates of the transport of Product A to the silos and of the production lines are converted to the interarrival time. This is done as the simulation programme uses the interarrival time. Also, the prioritization of the silo is elaborated on, as that is crucial to reflect the current situation at Company X.

Solution Sub-question 4

Lastly, the most beneficial solution to increase the production of products containing Element F is discussed. To answer this question, multiple experiments are run with the simulation model. First, the current situation is run in the model, to showcase the model returns values that resemble what is currently produced. Then, the inflow of Product A is increased in minor steps. This is only done during the weekdays, as it is easier to increase the weekday-inflow than the weekend-inflow. Besides this, more production slots are given to the production lines. In doing so, there have been run five different experiments of adding slots to the third production line. Per experiment, 10 runs have been performed, increasing the inflow of Product A into the silos. Hence, a total of 50 sets of results have been retrieved from the simulation model. These results have been thoroughly analysed with the graphs that are made using the code and graph objects in the simulation model. The graph that was mainly used for the analysis is the graph that shows how much production line 3 produces per shift. The throughput per production line is also mainly used for analysing the results, as mentioned in the conceptual model. In general, around 0.8 Units can be produced more per year if the suggested changes are implemented. The produced Units per year improve even further if Company X focuses on retrieving Element F from Product A. According to the graphs that are created in the simulation, the silos could handle the increase in extraction of Element F from Product A.

Conclusion

By performing the simulation of the production at Company X, the thesis shows that Company X could reach the goal. However, the extraction of Element F from Product A needs to be consistently higher.

Furthermore, implementing the suggested changes can increase the yearly production of products with Element F with 0.8 Units. Two possible solutions are mentioned, which depend on the preference of Company X with regards to the produce per production line. It does need to be mentioned that improving the production on one production line, usually comes at the cost of the production of another production line. The simulation model shows this for most experimented scenarios.

Recommendation

Three recommendations are made in the thesis. Firstly, Company X should add shifts to their production to achieve the yearly increase of 0.8 Units. Secondly, Company X should put more focus on which item to produce when. The length of the set-up times highly depends on the order of products. Hence, it would be worth it to dig into the so-called Job Shop at Company X. Lastly, Company X should focus more on the extraction of Element F from Product A. This is very important for Company X, as it costs them nothing, and results in more income.

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