Master Thesis – Public Abstract

How to Simulate Global MRI Backend Supply Chain at Philips?

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This research project emerged from my master Industrial Engineering and Management at the University of Twente. This thesis is the final stage of my study track Production and Logistics Management. The goal of the research was to reduce the takt time of a specific product family and to improve the logistics flow. The research encompassed the entire supply chain and perfectly suited my range of study. The execution of this research was a very inspiring and challenging learning experience for me.

The research was executed at Philips Healthcare. I worked with great pleasure over the last seven months at Philips. I am very grateful that I had the chance to work in such an interesting, innovative and technical environment. At the moment of writing, this work is finished and it is time to express my gratitude to contributors.

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1 INTRODUCTION

This report describes the research performed at Philips Healthcare in Best (the Netherlands), in the field of global supply chain management. This research is executed within the framework of completing Industrial Engineering and Management master study at the University of Twente. By the efforts spent within the scope of the project, the system in supply chain and the relations between departments and stakeholders have been examined, related problem is specified and a proper solution approach to the specified problem is offered. The project involves modeling the current supply chain of Magnetic Resonance backend system and measuring the performance of different supply chain scenarios and settings in order to prove the usability of the simulation concept in improving the current supply chain and giving the management an insight on the possible improvement/investment areas for their future decisions.

2 RESEARCH DESIGN

In today's volatile and competitive business environment, companies feel more the pressure of meeting their customers' demand on time, with the right conditions. There is an increasing trend towards market responsiveness (Wu & Golbasi, 2004). Besides, the project sponsors were dissatisfied with high inventory levels throughout the entire supply chain. They were looking for ways to improve the overall supply chain performance to overcome these issues and to enhance the cost effectiveness as well. In addition to its global nature, MR supply chain has other aspects making its effective management considerably important. MR machines are high-tech, capital intensive medical devices. Hence, the inefficient management of processes has high cost implications through the whole supply chain. Therefore, managing the entire supply chain effectively and improving continuously is a key success factor in such an environment. To achieve these and maintain their competitive position, it is needed to have a well-established understanding of their material, cash, and information flows. To illustrate, a clear understanding of current supply chain processes, with its weaknesses and the opportunities, and estimating accurately the effects of decisions to be made are essential.

In this SC context, the complexity of the system is significantly high and the processes are highly stochastic. Existing analytical methods are not able to handle all the dynamically changing supply chain variables. It is hard to derive closed form analytical models regarding the complexities (Mishra & Chan, 2012). Instead of using a traditional analytical model alone for a dynamic SC network analysis, simulation approaches can provide an alternative way. Simulation models are commonly used and they are effective to seize the impact of such system dynamics and uncertainties in a supply chain network (Ko, 2006; Tonanont, Yimsiri, & Rogers, 2010).Thierry et al. (2008) suggests that a modeling and simulation approach is the only suitable option to study the performance of such a large scale situation.

In conclusion, the main objective of this study is to develop a simulation model which can be used to provide managers in Philips MR Operations with support for decision making, as regards their global supply chain. This research first focuses on analyzing the current supply chain of MR backend system to verify the applicability of discrete event simulation in this context. It is also expected to help identify the opportunities of performance improvement in the current situation e.g. cost, inventory and lead time reduction.

The following research question needed to be answered to achieve this research goal:
In which way can a simulation model be built and used in order to correctly model the MR global backend supply and demand chain and to improve the system performance?

3 CURRENT SITUATION

The project started with an explorative process and data analysis and with delineating the research field. The conclusion of the analysis of the current system was that the major possible causes of the research problem are:

- Low, fluctuating and volatile demand
- Some critical components with long lead times and quality issues
- Bias in forecasted demand
- Customer specific systems: high configuration varieties
- Long end-to-end lead time

4 THEORETICAL FRAMEWORK

Supply chain simulation can be used to see how a designed supply chain performs and behaves over time when different rules and policies are applied rather than to produce an optimal supply chain structure or design (Shapiro, 2001). It can be used to evaluate different alternatives and to choose the best one among them. Simulation allows supply chain evaluation with regard to several factors:

particularly important ones to assess are the dynamic, stochastic elements and interactions among them.

Supply chain simulation is studied by many researchers. Since it is a complicated task, some studies concentrate only on specific aspects and limited parts of the supply chain. Each has excluded from their studies, some echelons, some nodes at each stage or some activities that are usually performed. Simplifications are not only limited to the size of the model to simulate. One needs to make some further assumptions to translate the reality and the data into a simulation model. The important thing is that the model should be able to demonstrate all essential aspects of the supply chain which assist the user to extract conclusions(Chan, Tang, Lau, & Ip, 2001).

5 CONCEPTUAL MODEL

Since one of our objectives is to test and prove the usability of discrete event simulation as a means of decision making for the MR supply chain, we need to create trust in the solution generated by the model for the stakeholders involved. The model developed has to be easy to understand and should provide outcomes which are easy to interpret and as decision makers would expect. As a result, we are currently focusing on a small subset of the MR backend system supply chain.

Due to the dependency of supply chain settings such as inventory replenishment parameters for assembly components on total demand, it is not convenient to reduce the size of the network by excluding some customers' demand. Instead, we have decided to reduce the number of suppliers to one. Due to the fact that there are no interactions between different suppliers, reducing the scale of the network in terms of suppliers would not affect the validity of the model. As a result, initial scope is to involve one supplier, which is responsible to control and replenish one of the basic MR components inventory in Philips' warehouse.

In order to select which supplier to include in the model, we have conducted some data analysis, and also discussed with the involved stakeholders which components they would like to prioritize. We based our decision on the criteria such as the value of parts, quality problems faced, the variety of components purchased, and so on.

Among the suppliers of the main modules, one of the engineering companies is chosen to be included in the basic simulation model. Reasons for this are:

- The company delivers a part which is an important MR component and exists in each system.
- There are four different types of that part in total supplied externally, which complicates planning activities and increases total inventory for that part.
- Philips experiences interesting problems like long lead times, quality problems and complete and on time(C&OT) delivery issues with that supplier.

The next step is to describe in detail the processes and dependencies taking place within the units which will be included in the model and to clarify the ones which will have an influence on the simulation model. However, we cannot share this information due to its confidentiality.

For reasons of simplicity and clarity, the original case has been simplified in several respects and is described in rough detail. Due to the limited time and complexities included within the system, the end-to-end supply chain is modeled on a high aggregation level by including only critical processes and settings. For example, we have reduced the number of suppliers to one as a starting point as mentioned before. Other model parameters have been adapted to accommodate this. Besides, in order to study the functioning of and relationships in the system, one needs to make certain assumptions to demarcate the reality and these assumptions form the basis of modeling that system.

Components of Simulation Model

As the last step before building the technical model, we present the main components in a simulation model to finalize conceptualization. In this section, we first name and explain these components and, then provide a list for each component to show their content as they will be used in our simulation model. There are four main components. These are:

- ***Input data:*** These are input parameters that will not change during simulation runs and experiments.
- ***Stochastic variables:*** These are incontrollable variables and their values are subject to chance variations.
- ***Experimental factors:*** These are controllable variables used to evaluate different control mechanisms and settings.

- ***Output data:*** This data results from a run of an experiment. Output data can be both used to validate the model assumptions and evaluate alternative control mechanisms.

The input data, stochastic variables and experimental factors used in the model are summarized below:

Input Data	*-Weekly demand forecast* *-Initial inventory on hand* *-Initial stock in the pipeline* *-Weekly production capacity* *-Product mix regime* *-Safety stock* *-Cost per MoT per quantity* *-Order Properties (Order due date, content, MoT, region of customer, and so on)* *-Percentage of defective parts at arrival* *-Inventory holding cost per unit per time period* *-Transit time per lane per mode of transport*
Stochastic Variables	*-Replenishment quantities selected based on alternative policy rules* *-Order processing time* *-Waiting time in stock*
Experimental Factors	*-SMI control policy rules* *-Variety of parts* *-Forecast accuracy* *-Shipment batch size (MOQ)* *-Frequency of shipment/ replenishment* *-Transportation time per MoT*
Output Data / Performance Measures	*- Percentage of orders shipped on time* *-Total number of shortages* *-Part availability as a percentage* *-Inventory level* *-Inventory holding cost* *-Inbound transportation cost*

After detailed analyses, a conceptual model is designed that forms the base for our simulation model. Determining the scope and the level of detail, identifying the processes which will be included in the model, demarcating the reality, developing control rules and logic which will run the simulation model, and revealing the model components and their content are basic steps to design a simulation model and to create a conceptual model. By following these steps and translating the conceptual model into a computer model, we get our simulation model developed. We use this simulation model to perform experiments of alternative solutions after verifying and validating the model itself. When the model is mature enough, it will be used as an instrument to test alternative control mechanisms before changing them in the reality. The reason behind is that the management wants to have a better control and more insight on the results before they make any related decisions. In this case, how we design the simulation model is important.

6 SIMULATION MODEL

Model Overview - Basic Structure

In this section, we describe the basic structure and construction of the simulation model. Our model is designed to help project stakeholders to prove the usability of discrete event stochastic simulation in supply chain related decision making in situations similar to that experienced by MR global operations, rather than reproducing the real world exactly. The simulation model is built in the software package *Tecnomatix Plant Simulation (version 11)*.

There are four major frames in the computer model in order to improve visualization. Here we explain roughly what these different frames consist of:

- ***Model:*** It contains manufacturing and shipment decision processes taking place at the supplier side, and also activities carried out at the sponsor company's warehouse, namely, receiving supplied parts, inspection, picking the ordered components, shipment to the key market.
- ***Event Control:*** The settings to start, to trigger weekly and daily routines, and to end the simulation run; the procedures to load data, to set and reset the initial conditions in a replication, and to manage experimental settings are all controlled by the blocks situated in this frame.
- ***Settings & Controls:*** Input parameters and stochastic variables mentioned are exhibited within this frame. Besides, the methods controlling the use and edit of this data are also provided within this frame.

- ***Performance Measurement:*** This frame contains table files collecting daily inventory levels, and order specific data each time there is a shipment from the sponsor company's facility. Overall performance is measured using the data from these tables and other parameters and variables from the model.

Input Data Analysis

We use historical order data from 2014. The reason for using actual data for order characteristics instead of generating random orders by the simulation itself is to increase the credibility of the simulation model since one of our aims is to prove the usability of discrete event simulation for decision making within the context of Philips MR backend supply chain. By using the actual data we can validate the model by comparing the results from the simulation model with what was the outcome in reality. In this way, it is also possible to compare the results of various scenarios that have the same basic input to better isolate and understand the consequences of the variations experimented. As a result, stakeholders of the project can get more insight into the model especially when a comparison between the current situation and the effects of different settings are presented.

However, we conducted data analysis to quantify stochastic variables such as processing times and defective parts rate on arrival. No statistical distributions are found to reflect the variability in these time related measures. As a result, we decided to use an empirical distribution generated from historical data, based on which the simulation model determines a value for the corresponding time variable for each single order separately. We cannot share this procedure due to its confidentiality.

To determine values of other parameters such as costs regarding transportation and inventory holding, we conducted interviews with involved stakeholders such as logistics and operations employees and set the values in the simulation accordingly.

Technical Details

Since results of the simulation will depend on random variables driving the model, the resulting averages are also acting as random variables. Therefore the number of independent runs has to be determined in order to construct a confidence level for performance indicators. We use a sequential procedure (Law, 2007) to find appropriate number of replications for our simulation model. It adds replications at a time until the specified relative error, which is an indicator of confidence interval half width's ratio to the mean value of the performance measure, has been reached. We applied the sequential procedure on the performance indicators *On Time Percentage* and *Total Cost*. With a 95% confidence interval and a relative error of 0,010 we have found the minimum number of independent replications based on the *Total Cost* to be 30.

After finding the values for input parameters, stochastic variables and simulation design parameters we can run our simulation model. However, before we can use the results of the simulation model in decision making, we first have to check whether the assumptions are correctly translated into the computer model, and whether the simulation model is an accurate representation of the system. These two procedures are respectively called verification and validation, and are described in the following two sections.

After we apply some methods for verification and validation purposes, no obvious unintended functioning has been detected. As a result, we state that the conceptual model has correctly been translated into the simulation model. The computer model is found to represent the current system accurately, based on the tests carried out.

All in all, from this analysis we can conclude that the current model is a good start to model the current MR backend supply chain. However, it needs to be extended for other supplied components and for each additional supplier similar analyses should be conducted to validate new assumptions and in order not to ignore interactions between different factors.

7 EXPERIMENTAL DESIGN

As one of the main objectives of this research is to prove the usability of discrete event simulation to make decisions within the context of MR backend supply chain, we need to demonstrate that our simulation model is capable of creating insights for the management on improvement areas (i.e., where to focus their attention on, in order to achieve improvements). This is possible by presenting system behavior and performance (e.g. simulation outputs representing performance measures) under different control rules and settings.

In order to show how the system behavior and performance would change when using different controls, we designed some experiments. We split our experiments into two main sets. We first decided to analyze and show the effect of factors which require structural changes. *The variety of parts, forecast accuracy, shipment size and shipment frequency* are the factors which were included in the first set of experiments.

We consider deviating these factors from their current settings. Hence, we aim to analyze the impact of these interventions, and also whether there are interaction effects between these factors. Law (2007) describes a 2^k factorial design as a strategy which can measure both the effect of each single factor and also the interactions between all the factors. A 2^k factorial design means that there are k factors to evaluate and for each of them we should select two different levels or rules to experiment. This will lead to 2^k possible factor-level combinations. In this case we have four factors, and 16 resulting experiments to perform with simulation in the first set of experiments.

Then, we introduced further experiments with different levels for numerical factors based on the results of the first set of experiments. Namely, these factors were *lower and upper stock limits for each part type; MOQ for regular boat shipment; and transportation lead time.*

8 RESULTS

We cannot share the numerical results due to their confidentiality. However, we present some of our findings as a result of the data analysis we conducted. The results of the analysis show that improving the forecast accuracy, changing the available number of options for parts and changing the shipment size would change the total cost significantly. It is observed that among the factors studied changing the number of part options would bring the highest benefits in terms of system costs. However, it requires more careful analysis before decision making including stakeholders from several departments such as marketing, sales, product design, procurement, and so on. Among those, the only factor that can bring some significant improvement on the SC performance in *the short term* was the "shipment size" among the ones experimented so far.

According to the results of the second set of experiments, increasing MOQ slightly reduces the availability due to the fact that the time between shipments gets longer with the increase in the shipment/container size. However, it decreases total cost as well. Even though the smaller lead time is expected to give better results, it is observed that having a very short lead time performs closely in terms of total costs and a lead time of middle range outperforms the shorter one in terms of availability due to the system dynamics.

9 DISCUSSION AND CONCLUSION

Designing and building a simulation model which imitates the current processes in MR backend supply chain provided us and the company stakeholders with a well-established understanding of the material, cash and information flows throughout the whole SC by examining the operation of the system in detail. We currently focused on a small part of the MR backend system supply chain in our simulation model due to the reasons such as time limitation, intensity of the data and information to be included and difficulty of debugging with a huge model, and so on. However, we paid attention on not excluding highly dependent and interacting elements. As a result, we narrowed down the SC by reducing the number of suppliers, and thus the number of assembled components in a backend system. Besides, a high level of abstraction is used when modeling the processes. For this subset of the MR backend SC, we observed that what happens in reality also happens in simulation. Thus, the simulation model is capable of reflecting accurately the operating of the current SC processes. It can accommodate the complexities and dependencies present in the real system. It also helped us to consider several metrics simultaneously (e.g. cost, service, lead time, inventory).

In addition to understanding the current situation by presenting results from the baseline model, this study gave more insight on the behavior and performance of the system enabling us to identify the impact of various decision making scenarios on performance measures. Therefore, we have proved that supply chain engineers and managers can accomplish their overall objective by evaluating different SC strategies and settings by the help of discrete event simulation. The developed simulation model was used as an instrument to test alternative control mechanisms without changing them in reality for the related part of the SC. The current model can be extended easily by adding other components and their procurement processes, and also gives the possibility to conduct different experiments than the ones we did. As a result, Philips management can have a better control and more insight on the results before they make any related decisions by comparing various alternatives and evaluating several control policies in shorter time without interrupting the real system.

Moreover, assessing and evaluating various what-if scenarios with the simulation model and carrying out numerous replications corresponding to different possible situations can help to design a robust and resilient SC against unexpected events, uncertainties, and their interactions since Philips is facing rapidly changing environment in MR business. Important factors such as inventories, lead time, customer demand, and so on corresponding to the uncertainty of the environment in which the SC activities evolve could be considered with the designed simulation model. As a result, the simulation model will be used in the organization as a decision support tool which gives the ability to analyze the supply chain processes and to evaluate the alignment between the changing business environment and its supply chain settings, by observing the impact of possible design and management decision scenarios on the overall SC performance.

All in all, simulation does not guarantee an optimal design. However, this technique offers a real help in establishing and in evaluating the consequences of alternative decisions. It gives the possibility to evaluate the supply chain performance on a regular basis and, to adjust and rebuild the plans on time considering system dynamics. It helps identify the opportunities of performance improvement in the current situation e.g. overall cost, inventory and lead time reduction, improvement in suppliers' performance, improved material and information flow, and so on . The simulation helps answering questions such as: Are investments required in the current setting? If investment is required, where to invest and what improvements can be expected? What is the bottleneck within the system to achieve? Is the system flexible enough to cope with the changing environment? and so on. Therefore, it helps to manage the supply chain more effectively and improve continuously.

To conclude, we should indicate that the current model is a good start to model the current MR backend supply chain. However, it needs to be extended for other supplied components and for each additional supplier similar analyses should be conducted to validate new assumptions and in order not to ignore interactions between different factors.