Impact of End-to-End Lead Time on Service Level and Working Capital in a Pharmaceutical Company

By Thilo Girsch and Kristin Bautista

Thesis Advisor: Professor Alejandro Serrano

Summary:
This thesis answers the question of how far can end-to-end lead time and working capital be reduced while maintaining an acceptable service level. We use an analytical and a simulation model applied to two products having different demand patterns (growth and maturity) in a multi-echelon setting. We find a significant reduction potential for end-to-end lead time and working capital of products while maintaining an acceptable service level.

M.E. in Logistics and Supply Chain Management, MIT-Zaragoza International Logistics Program

Diplom Wirtschaftsingenieur (FH) University of Applied Sciences Wiesbaden

M.E. in Logistics and Supply Chain Management, MIT-Zaragoza International Logistics Program

M.S. in Materials Science and Engineering, University of the Philippines

KEY INSIGHTS

1. There is an identified reduction potential for the end-to-end lead time and working capital while maintaining an adequate service level.

2. The biggest incremental change of the working capital is observed when reducing upstream inventory.

3. E2E LT is endogenously mostly affected by order interval, lead time, and batch size. Exogenously, demand growth and variability play an important role.

Introduction

As pharmaceutical companies try to reduce manufacturing costs through lead time reduction, the challenge of maintaining a high customer service level remains. It is significant to know the impact of a change of the end-to-end lead time on the order fulfillment performance and its influence on working capital.

End-to-end lead time (E2E LT) is defined as the time from the raw material purchase order to the delivery of finished goods. It includes the time a product spends in inventory at each production step (which we define as the Material Days Coverage or MDC). The length of E2E LT is, thus, related to the working capital that the company holds to fulfill demand. If E2E LT is longer, the company holds more inventory. If E2E LT is reduced, the inventory at the different production steps has to be reduced, which leads to cost reductions.

In this work, we provide the company with a strategic direction and insights on where and how much E2E LT and working capital can be reduced while maintaining an adequate service level. We investigate the impact of E2E LT on working capital and service level. Specifically, we find a solution to the proposed research question of how far E2E LT and working capital can be reduced while maintaining an acceptable service level.

Methodology

We answer the research question through the use of an analytical and a simulation model that we apply on two products having different demand patterns (growth and maturity). A common supply chain framework is established to allow for comparability between the two products. This framework is used as a basis for the two models. In the analytical model, we apply a periodic review policy to a multi-stage serial system to investigate how sensitive the MDCs and the service levels are to changes in key variables of the supply chain. Finally, we use a simulation model as a more realistic representation

of the E2E supply chain to quantify the reduction potential of E2E LT. Furthermore, we use the simulation to evaluate the financial impact of an E2E LT reduction. The model also allows us to compare the products' E2E LT under consideration of shared production capacities and changes in demand growth and variability.

Supply Chain Framework

Our work focuses on two products at different stages in the product life cycle (growth and maturity). The pharmaceutical products are manufactured and distributed in geographically dispersed facilities. Given the vast amount of data and the geographical differences for both products, we define a common supply chain framework that allows us to find a common and adequate level of aggregation for our work.
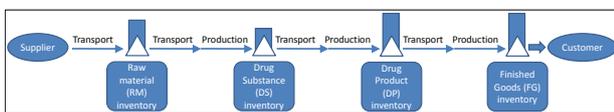
As shown, the supply chain can be segmented into four different inventory stages for all products: the inventory stages of Raw Material (RM), Drug Substance (DS), Drug Product (DP) and Finished Goods (FG). At each of the described stages, inventory is needed to keep an adequate service level.

Analytical Model

In building an analytical model, we look at how key variables at each inventory stage impact the service level through a sensitivity analysis.

We use a periodic review policy (inventory is checked at regular periodic intervals) and apply it to a multi-echelon setting. We formulate a minimization problem for each inventory stage to find the lowest possible MDC given a service level constraint. We combine the derived MDC figures to calculate the E2E LT.

The analytical model is mainly influenced by the assumptions that stock-outs in one stage do not lead to a delay in the lead time to the next stage and that production capacities are not shared with other products. Despite these limitations, the analytical model gives us insights on the mechanics of each stage in the supply chain network. To remove some of these assumptions and thus allow for a more realistic model, we investigate the two products using a simulation model.

Simulation Model

The simulation model provides us with a more realistic representation of the products' E2E supply chains. Using the simulation software Rockwell ARENA®, our model allows us to consider demand growth and variability. Contrary to the analytical model, it allows us to consider the delays caused by stock outs in previous inventory stages and shared production capacities.

Another important parameter that is considered is the monetary value of inventory at the different stages. Thus, the simulation allows us to create different scenarios to evaluate the required working capital at each inventory stage and in total.

Reduction Potential for E2E LT

We used both models to quantify the reduction potential for the E2E LT considering a minimum service level (fill rate) of 96%. The figure below shows the results. The more realistic simulation model leads to a lower reduction potential as it accounts for delays in the lead time due to stock-outs and allows considering shared production capacities.
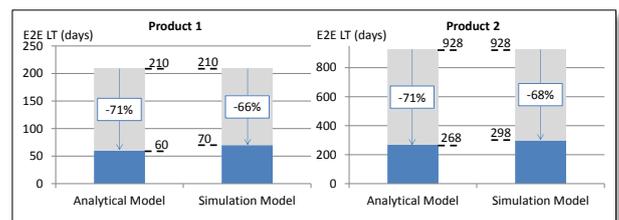
Looking at the high reduction potential identified, it is important to keep in mind that the models do not allow us to factor in many risk related inventory decisions. For example, the company has to consider the probability of supply chain disruptions caused by accidents or natural catastrophes. Such risks are not included in the models and would significantly lower the reduction potential of the E2E LT.

Impact on Working Capital

The impact of the identified E2E LT reduction potential on the working capital was quantified using the simulation model. We reduce the inventory in four scenarios starting with the downstream inventory stage moving to the upstream inventory stage (see figure below). Comparing the "as is" with the optimized scenario, we found a significant working capital reduction potential of 84% (754k to 122k currency units) for product 1 and 86% (121k to 17k currency units) for product 2.
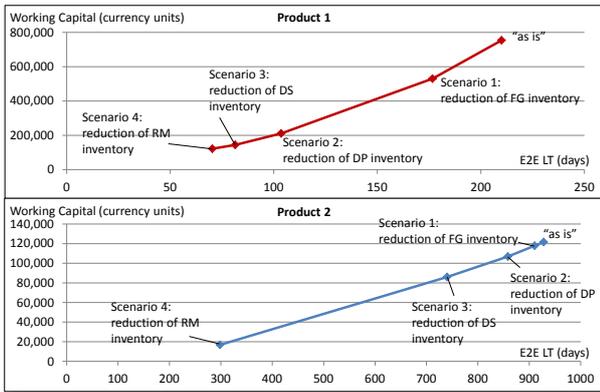
It is apparent that the reduction of an inventory stage further downstream leads to a steeper reduction of working capital compared to a reduction of an inventory stage further upstream (*e.g.* product 1 finished goods reduction = 7k currency units per day; raw material reduction = 2k currency units per day).

Endogenous Parameters Influencing E2E LT

The E2E LT is endogenously mostly affected by the order interval, the lead time and the batch size. An additional analysis shows that shared production capacities have a high influence on the E2E LT. For product 2 we evaluated how E2E LT changes when shared production capacity at one stage is changed to dedicated production. We found that the overall E2E LT in this case can be further reduced from 298 to 278 days. Thus, shared production has a high impact on E2E LT.

Exogenous Parameters Influencing E2E LT

Exogenously, the E2E LT is sensitive to changes in the demand growth and is significantly impacted by demand variability. Interestingly, the E2E LT increases rapidly in a certain range of demand variability (see figure below). Outside of this range incremental changes in the variability have a lower impact on the E2E LT. This is of significant importance to the company when a reduction of E2E LT is intended.
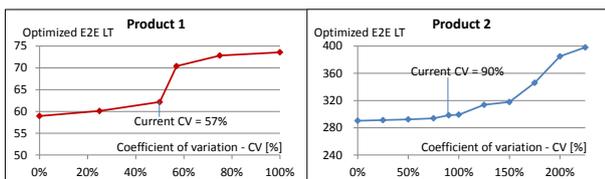
Recommendations

We recommend the company to revise the demand variability of a product throughout the life cycle of a product. We have shown that demand variability is a very important factor for the adequate E2E LT of a product. Thus it is important to keep close track of demand variability and revise the E2E LT accordingly. In addition, we have found that demand growth is also impacting the E2E LT of a product. Similar to the demand variability, we suggest that the company should monitor demand growth and revise E2E LT accordingly. Finally, we recommend that the company should mainly focus on reducing inventory downstream. This has the highest incremental impact on the working capital.

Potential Next Steps

Our work could be used as the basis for practical initiatives to reduce the finished goods inventory. Once an adequate inventory level is reached, the company can focus on the upstream inventory stages subsequently. The provided E2E LT reduction potentials can serve as a guideline for the maximum reduction possible. The risk of supply chain disruptions has to be taken into consideration separately for the respective inventory stages. The reduction initiatives could first be focused on lower risk inventory stages.

In addition, the study could be used for further research that could be carried out to evaluate as an example the service level differentiation for the offered products. The company might want to have a higher service level for launch products and reduce the service level for products with declining demand. For the latter, substitute products might already be available and overstocking should be prevented. Thus, the service level does not necessarily have to be very high. It might lead to a significant improvement potential in the employed working capital and the E2E LT, when service level differentiation is considered.

A subsequent study could also involve a more finance-driven objective function that incorporates setup costs, inventory holding costs and/or penalty costs for backlog. Also, the programming could include multiple products and capacity constraints for the different production steps, allowing for an even more realistic model. Such a model could be used in a complementary way for operational decisions, while the simulation model that we prepared serves as a subsequent analysis for strategic decisions.

Major References

Chopra S., M. P. (2010). *Supply Chain Management, Strategy Planning and Operation* (Bd. Edition 4). Prentice Hall International.

Silver, E., Pyke, D. and Peterson, R. (1998). *Inventory Management and Production Planning and Scheduling* (Bd. Edition 3). John Wiley & Sons.