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# The Application of Data Management Technology in Implementing Inventory Model - Semiconductor Industry

## Business Case Study

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## Abstract

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This thesis studies the inventory planning model designed for Silicon Laboratories Finland Oy. The study took place when the case company adjusted its inventory strategy after the supply shortage caused by the COVID-19 pandemic. In response to the circumstance, the paper aimed to explore the advantages of the new inventory model for the company and proposed an initial implementation plan leveraging the advanced data management platform.

The essential theories such as the utilization of forecast data to optimize inventory planning and the achievement of a competitive edge through logistics planning were underscored. The new inventory model can assist in the enhancement of coordination among diverse departments and bridge the information gaps within the supply chain effectively by using an advanced data management platform. Due to the practical aspect of this study, a mixed method approach between the quantitative research method and project-based method was employed. Data was gathered through meetings and emails to harness actual information. Thus, all collected data was used to support the author and the team in analysing results and planning subsequent steps. Ultimately, the thesis aims to offer tactical recommendations for future implementation and unveil potential areas for further research.


Keywords: Inventory Model, Semiconductor Industry, Data Management Platform, Forecast & Inventory Management.

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## Terminology

Fabless: A company proficient in semiconductor design yet lacking a manufacturing facility for production (Samsung, 2013).

Foundry: A semiconductor fab, or fabrication, is a production facility where raw silicon wafers are transformed into integrated circuits (ICs) (TechTarget, 2023)

Node technology: The technology node (also process node, process technology or simply node) refers to a specific semiconductor manufacturing process and its design rules. The smaller the technology node means the smaller the feature size, producing smaller transistors which are both faster and more power efficient (WikiChip, 2022).

Wafer: A thin, circular slice of single-crystal semiconductor material cut from the ingot of single crystal semiconductor; used in manufacturing of semiconductor devices and integrated circuits (Nova Electronic Materials, 2023).

Die: A simgle semiconductor piece encompassing a complete, unpackaged integrated circuit; commonly known as a chip (Nova Electronic Materials, 2023).

Cycle stock: Inventory needed to satisfy the average demand during the time from placing an order to receiving the goods, considering the order lead time or cycle time (Gant, 2012).

Safety stock: Inventory needed to support fluctuations in demand beyond the anticipated fulfilment within the lead time (Gant, 2012).

Pipeline stock: Inventory either in the process of production internally or in transit externally (Gant, 2012).

# Abbreviations

| | |
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| APIs | Application Programming Interfaces |
| AR | Action Research |
| CPFR | Collaborative Planning, Forecasting, and Replenishment |
| CSL | Cycle Service Level |
| DMP | Data management platform |
| FGI | Finished Good Inventory |
| ICs | Integrated Circuits |
| ICT | Information and Communication Technology |
| KPIs | Key Performance Indicators |
| LTD | Lead Time Demand |
| ROP | Reorder Point |
| R&D | Research and Development |
| SnOP | Sales and Operations Planning |

# 1 Introduction

This thesis has two main parts. The first is to explain the logic of the inventory reorder point planning model and to show how to implement a new inventory model in the case company – Silicon Laboratories Finland Oy, which is also known as Silicon Lab. The second is to explore how unifying data management platform support collaboration between different departments. The model is built with the goal to optimise inventory level while minimising the inventory costs by monitoring the reorder point and reorder quantity in the future. The motivation of this study is to learn about semiconductor supply chain and inventory management while combining the knowledge and interest of the author in data management technology and business analytics.

## 1.1 Background

### 1.1.1 The current Situation of the Case Company's Supply Chain

The case company is a semiconductor company without a production line – known as a fabless semiconductor company. In fact, the semiconductor industry has rich experience with offshoring manufacturing activity. According to Brown, Linden and Macher (2005), this industry was one of the pioneers in investing in offshore facilities to manufacture products and import them back to the United States. In other words, fabless semiconductor companies outsource their manufacturing process to third parties while focusing on product design, marketing, and sales functions. With this strategy, fabless companies are not only avoiding dealing with internal resources associated with running the manufacturing facilities, but they also have an open-door in cooperating with any foundries that are on par with their criteria regarding technology, price, service, location, etc. (Hurtarte, Wolsheimer and Tafoya 2007). Consequently, there are many advantages of using an extended-enterprise model, where a company dedicates to its core competency and outsources other functions, compared to having a vertical-integration model, where all functions are performed in-house.

However, outsourcing comes with its disadvantages. The fact that many layers have been added to the supply chain increases the level of information distortion and inefficiencies in the supply chain management flow. As Harrison, Lee, and Neale (2005) reported, information distortion leads to the bullwhip effect and results in excess cost.

On top of that, the COVID-19 pandemic in 2019 created tremendous disruptions in the production and supply of integrated circuits in general. The semiconductor industry was unprepared. The “chip shortage” problem that had started to emerge ended up causing a ripple effect in the entire production network. After the pandemic, these semiconductor companies are still finding ways to recover from the lack of supply to fulfill demand (Marinova and Briti 2021). To achieve that, there are many aspects of the business that needed to be investigated and enhanced. This includes research and development (R&D) strategy, demand forecasts, sales, operations planning, etc. Among them, enhancing supply-chain efficiency is one of the crucial parts. In a nutshell, revising long-term strategies and reconstituting supply chain management is vital for semiconductor companies to reform stronger in the future (McKinsey & Company, 2020).

Christopher and Lee (2004) affirmed that a supply chain with high-risk exposure cannot perform at its best and can lead to mediocre performance. Specifically, the lack of confidence risk within the supply chain and the sales and operations planning (SnOP) management was mentioned here. This risk can happen due to several factors such as order cycle time, order status, demand forecasts given, manufacturing capacity, suppliers’ capacity to deliver, services delivered, etc. Without supply chain confidence, stakeholders within the supply chain are susceptible to chaos and end up contributing to the expansion of the risk spiral. An example of having a lack of confidence risk is an unreliable order cycle and order fulfilment. In this example, distributors would order at the overstock level just to ensure enough supplies to support key customers which can cause inefficiencies at a later stage. Another example that shows a similar reaction is the lack of visibility of the actual demand signals, as well as the lack of clear visibility among upstream and downstream flows of stocks. These weaknesses weaken the decision confidence, leading to the increase of inventory buffer to deal with uncertainty. As a result, the build-up of inventory introduces long pipelines and obstacles to the clear visibility of the supply chain (see Figure 1 for an illustration). Thus, the significant issue in managing supply, sales, and operation planning is the lack of visibility of the entire process and the lack of actual demand signals in collaboration process.

Additionally, the long and uncertain lead times in the manufacturing process is a significant obstacle for fabless enterprise to stay competitive. To compensate for that, fabless manufacturing companies must keep prominent levels of stock, which then could lead to obsolescence and higher inventory costs (Harrison et al. 2005). Hence, taking actions that help improve the level of coordination and information sharing within business partners or associated teams is one of the keys to improving the supply chain performance in general.

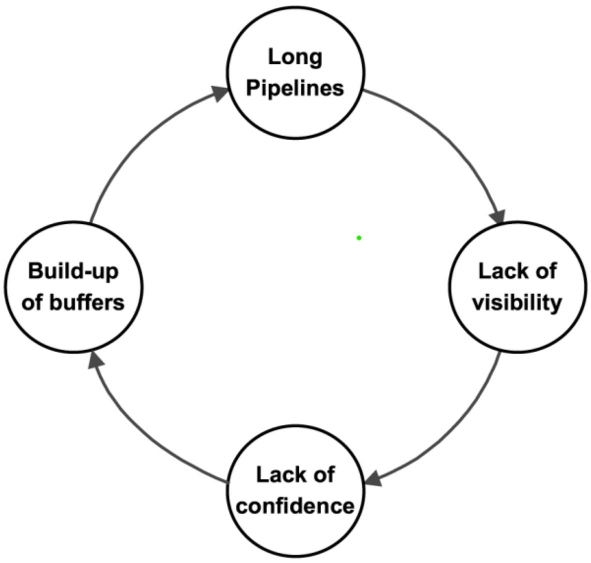


Figure 1 The risk spiral diagram (Christopher and Lee 2004).

In short, the risk spiral can occur anywhere in the supply chain. Fabless companies, therefore, must take actions to shorten time-to-market, speed up product development, lower cost per integrated circuits (ICs), etc., to remain competitive in the market (Harrison et al. 2005). Yet to break the risk spiral, raising confidence in the supply chain is the only way (Christopher and Lee, 2004).

### 1.1.2 Addressing the Problem

In this case company, some drawbacks of the current inventory management systems are detected, for example, the lack of optimising inventory calculation in the system in supporting all related stakeholders at the same time. Thus, the implementation of a new inventory optimisation model and a synchronising system/platform that can support business operation, inventory planning and marketing team at the same time is necessary. For that reason, this paper aims to present how to implement the optimisation inventory model and highlight how a new data management platform can support synchronizing information and collaboration between those teams.

### 1.1.3 About Silicon Laboratories Oy

Silicon Laboratories Oy is a fabless semiconductor company that develops and designs wireless and non-wireless chips and modules – hardware – together with IoT technology solution software. Founded in 1996 with headquarters in Austin, Texas, USA, currently, Silicon Lab has offices in Europe, North America, Africa, and Asia Pacific regions. (Silicon Laboratories, 2022)

The company's vision is to help solve global development challenges such as energy efficiency, sustainable cities, responsible production, infrastructure innovation, etc. Silicon Lab provides technology solutions across home, industrial, medical, smart cities, and commercial environments. Furthermore, this company provides its customers the opportunities to accelerate IoT business with the world's most popular ecosystems such as Amazon Alexa, Amazon Sidewalk, Google Home, Apple HomeKit, SmartThings of Samsung, etc. Thus, the collaboration with Silicon Labs provides a wide range of opportunities to reach out to a wide range of customers around the world. Since Silicon Lab supports the capability to connect with these ecosystems, providing strong competencies for expanding the customer base and utilising the advantage of trusted user experiences. Moreover, with a wide range of resources to support customers such as training platforms and events, developer tools, and community support, Silicon Lab shows its commitment to providing world-class services and products to its clients. (Silicon Laboratories, 2022)

## 1.2 Research Aim and Objective

The study objective revolves around what, why, and how to implement a new inventory model for the case company. Briefly, the thesis explains how the inventory model processes forecast data and other inputs to provide the re-order point in inventory planning, on that account, supporting inventory management tactic. Furthermore, the author sought a way to investigate the effect of applying this model regarding between related departments. To be more specific, there are two questions that the author aspires to investigate:

Question 1: What is the model about and how will it benefit the company?

Question 2: How to implement the model?

## 1.3 Thesis Structure

The rest of the thesis is organised as follows: Chapter 2 discusses the methodology used in this report; Chapter 3 goes through the theoretical background; Chapter 4 explains how the model work; Chapter 5 presents the model result, the initial action plan and next step; Chapter 6 regards the possibles limitations; and finally, Chapter 7 closes with the conclusion.

# 2 Methodology

This section outlines the method used to get to the answer to the research questions. Moreover, it describes how the data was collected and processed along the way.

## 2.1 Research Method

### 2.1.1 Action Research Method

Shortly, action research is a participatory approach to conducting research. It focuses on improving practical problems in a specific setting. Action research is an inquiry process to solve practical business problems by combining science with organizational knowledge. Often, action research involves with bringing about change in the system, especially in developing self-help competencies, while contributing to scientific knowledge. The goal of this approach is to identify, analyse, and solve problems in a collaborative manner. According to Karlsson C. (2016: 233 - 267), the researcher is also a participant who collaborates closely with stakeholders and has the possibility to collect data and suggest changes for a better outcome in action research. The results of action research are typically presented in qualitative terms, such as case studies or narratives. Data collection methods of action research are often interviews, case studies, or focus groups to collect qualitative data.

### 2.1.2 Quantitative Research & Simulation Approach

Quantitative research method is based on assessment of quantity or amount (Kothari, 2004). Quantitative research is valuable when it comes to analysing data, testing hypotheses, and making evidence-based conclusions. In other words, this approach is typically used in empirical research, such as surveys or experiments, to identify the relationship between variables and make predictions based on data. In addition, the data collection method in this type of research is standardized to ensure accuracy and consistency, thus avoiding personal biases, and maintaining objectivity. Meanwhile, simulation approach is one of a sub-classified of quantitative research method. Rigorously, in simulation approach, the creation of artificial environment is needed to generate relevant information or related data. This approach supports observation of dynamic behaviour of a system under controlled conditions or to understand the future conditions, given different conditions, parameters, or input values. (Kothari, 2004)

### 2.1.3 The Mixed Method Approach

As the goal of this study was to plan the implementation of the inventory model, the thesis is considered a project-based thesis. To plan the implementation of a new inventory model, a suitable research method is required to learn the current and the new inventory system, identifying gaps and inefficiencies.

As briefly described by Creswell, Clark, and Vicki (2018), mixed method is designed so that it includes at least one quantitative method (to collect numbers) and at least one qualitative method (to collect words). In this context of inventory management studying, action research is applied when the author collaborates closely with key stakeholders, for example, supply chain expert, operation management team, and forecast and data management team to understand the current inventory management process and name areas for improvement. The goal is to be able to build a plan and a simulation to highlight potential pros and cons when running a new model in the system. In fact, the action research (AR) method was chosen as the suitable primary method to be used in this study, since this research approach is concentrated on improving practical problems in a specific setting through collaboration and qualitative data collection. Additionally, the author decided to use a combination of action research and simulation approach to use the advantages of both methods and gain a more comprehensive understanding of the topic quantitatively and qualitatively.

## 2.2 Data Collection

### 2.2.1 Data Sources

As this is a business case study, the author used data provided by the company to analyse and conduct the testing process plan. In more detail, the author was able to request relevant historical data for the purpose of learning and testing hypothesis. The data which was used as input of the inventory model such as forecast data, average sale price, and lead-time estimation were provided by the data operation team. This data was consensus data, extracting from company database and available for internal user. Since the data was actively used, it was ensured with accuracy and reliability, meanwhile, it did not require much of the cleaning or transforming data before using.

Moreover, the author had the opportunities to acquire input and information through conversation, email, and discussion with other internal personnel. There was no formal interview conducted. Instead, the information collecting process involved with re-occurrent meetings or rescheduled meetings, conversations, and discussions.

### 2.2.2 Data Processing Tools

Briefly, three main data processing and analysing tools which are Excel, Tableau, and Power BI were used. Firstly, data were cleaned and computed into an Excel table. The author used the formulas presented in chapter 4 in Excel to create charts and pivot tables. Then the final Excel table can be loaded into Tableau or Power BI for better visualisation. This can also help blend and conjugate the uploaded data with other data sources for further study analysis.

About Tableau, it is a powerful data analytic and visualisation tool that helps companies employing business data resources. One of the key features of Tableau is the ability to support and connect different database types, including spreadsheets such as Excel files, databases, cloud-based services like Google Analytics and Salesforce, and other complex datasets (Tableau 2022). Therefore, Tableau is one of the ideal choices for enterprises to conduct business analysis across multiple sources of data. Besides, this software is well-known for its robust features with drag-and-drop functionality and a user-friendly interface.

The author considered Tableau and Power BI as significant tools used for visualisation, since their elements of dashboards provide the ability to drill down into data and explore the trends and patterns while having the data updated in real time. This helps streamline the data analysis process while saving time and resources instead of manually updating data and repetition task. If Power BI has smoothest transition from Excel formulas and data, Tableau on the other hand provides notable capability to integrate with other software and programming language such as Python, R. These features can enhance the capabilities by utilising programming in advanced data analysis and visualisation and thus, unlocking the opportunity to create custom workflows to automate tasks and create more comprehensive and sophisticated data analysis solutions (Tableau 2022).

### 2.2.3 Research Boundaries and Limitations

The study was defined to focus on the case company within its business environment. The characteristics of fabless semiconductor companies were considered in the initial study phase. Since the research's target is presenting a plan for implementing an inventory model, the scope of the report includes introducing applicable software, plans and solutions which are considered suitable to implement the model and to support further development of the project. Since the project is continuing to be conducted after the thesis report is finished, this report is presented as a preliminary plan for the implementation of the model in the case company.

# 3 Theoretical Framework

This part of the report provides the background knowledge needed to answer the research questions. For it is necessary to gain a basic understanding of semiconductor features regarding production lead-time, inventory forecast demand. Moreover, an overview of inventory optimisation and strategic communication and collaboration within the supply chain is also included.

In a nutshell, this part of the thesis includes – firstly, semiconductor production and different inventory phases are introduced; secondly, inventory optimisation and inventory planning are explained; thirdly, forecast process and other inputs are described; lastly, the application of data management platform is presented.

## 3.1 Semiconductor Inventory Features

The semiconductor supply chain is characterized by long production lead times. The complicated production process can be divided into three main stages, which are pre-assembly, assembly, and test operations (Sivakumar and Chong, 2001). The pre-assembly process lasts from three months to six months, beginning with wafer production till die inventory. Specifically, the chip production process begins with producing a cylinder bar made of 99.99% pure silicon (also called boule/ ingot) and polished to an extreme level of smoothness. The ingot then is cut into thin slices which are called wafers. Wafers typically have a diameter of 100mm, 150mm, 200mm, 300mm, to name a few. The bigger the wafer, the more integrated circuits – as known as chips – can be made from one wafer. Once the silicon wafers are cut from the boule, the full process of producing chips begins. The wafer manufacturing process takes from 3 to 6 months. Once the integrated circuit process is done, the wafer is then cut into pieces that are called die. The assembly production process starts from here, which takes from 3-6 weeks. After that, the product is stored as chips in the inventory for testing and is introduced or released as the final product later. Thus, there are three phases of how the inventory can be stored, namely, wafer, die, and finished good inventory (FGI).

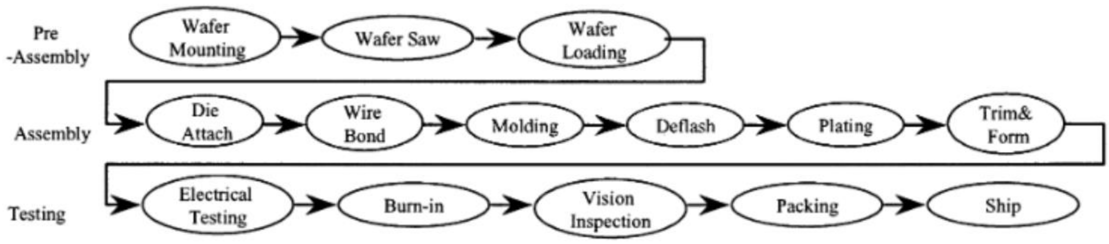


Figure 2 Simplified semiconductor manufacturing flow (Sivakumar and Chong, 2001).

Furthermore, wafer production lead time depends on the technology designed for the chips. The more advance the technology, the longer the lead time. For example, the physical size of transistors is one of the key node technologies for producing microchips. The smaller the size of transistors, the more transistors a chip can accommodate. Since transistors augment the capabilities of sending out instructions and increase computational power, the chips become more powerful. (Sivakumar and Chong, 2001).

## 3.2 Inventory Optimisation

Inventory optimisation is a vital part of sales and operation planning (SnOP) management to ensure target customer satisfaction level while efficiently oversee cost and opportunity cost (Chopra, 2019). In other words, while sales and marketing activities ensure the continuous of the revenue stream, forecasting establishes the best estimate of customer demand at the point of sale, inventory management aims for procuring sufficient level of stock based on customer demand and fulfilling certain customer satisfaction level.

For that reason, it is important to consider the types of stock and their aim to manage stock efficiently. In this report, distinct types of stock such as cycle stock, safety stock, and pipeline stock are taken into consideration. Often, inventories provide a buffer stock between customer demand and supply. Buffer stock is especially used to reduce customer waiting time, minimize the impact of supply discontinuity, and maximise the profit when demand ramps up. According to the risk spiral previously introduced, lacking trust and confidence leads to problems such as an excessive number of orders from sales, insufficient buffer stocks from inventory management, resulting in ineffective stock management in the pipeline. Having too many inventories on hand creates several disadvantages in financial efficiency performances such as opportunity cost, losses because of obsolescence and damage, extra taxes plus insurance costs, and other related factors while having too little inventory affects revenue, customer satisfaction, buying power to suppliers, and so on. (Grant and David, 2012: 96-99).

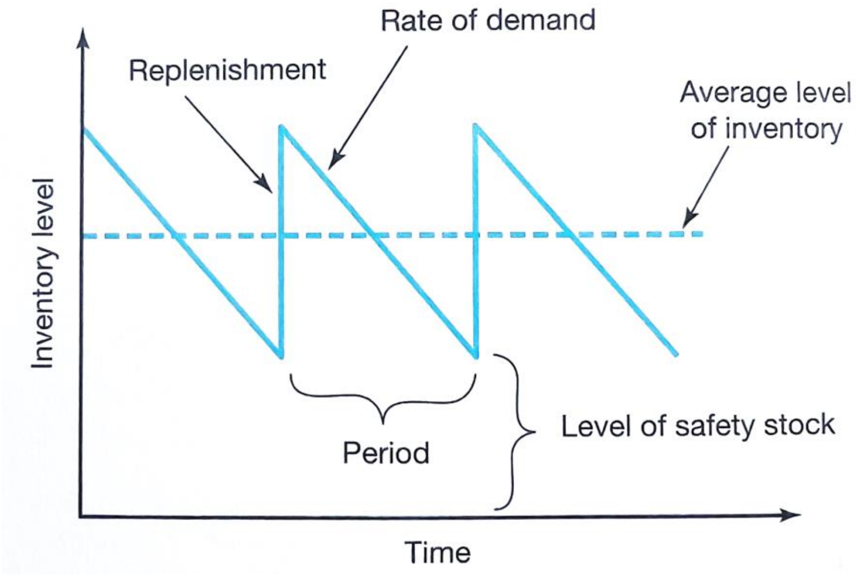


Figure 3 Classic ‘sawtooth’ inventory cycle and replenishment diagram (Grant et al, 2012:100)

Thus, when it comes to inventory management, some enterprises aim as inventory optimisation. The idea is to support the system in reacting to a predicted demand in a logical and optimized way, while maintaining an effective stock balance level between the demand and supply. Concisely, organisation ought to have a decent level of stock to meet target customers’ satisfaction level, while continuously checking stock-out risks. In this study, the Customer Service Level calculation is presented as one of the inputs of the optimisation inventory model.

## 3.3 Competing Through Logistics Planning

The effort of “efficient customer response” requires collaboration from the whole supply chain, meaning all parties need to buy into the idea. This cannot result from the effort of a single stakeholder in the chain. The Collaborative Planning, Forecasting, and Replenishment (CPFR) business practice is built for this purpose. This practice requires the intelligence of multiple partners, an established standard for the exchange of information, and synchronised data to plan and fulfil customer demand (Chopra, 2019). To elaborate, in the strategy and planning step, all partners need to set up the scope of partnership and collaboration. The roles, responsibilities, and checkpoints ought to be decided at this stage. In the business collaboration plan, all parties should be aware of remarkable events such as new product introductions or changes in inventory policy that influence demand and supply incentives.

In relation to the demand-supply management phase, a synergetic sales forecast should be generated by the associated parties to best assess consumer demand at the point of sale. Then, order plan controls future orders, and the delivery requirements will be based on sales forecasts, replenishment lead times input, and inventory positions from relevant teams. Following up, the inventory plan is executed to fulfil actual orders. Eventually, the analysis phase is implemented to evaluate the metrics, assess performance, and identify trends, exceptions, and other risks. (Chopra, 2019)

## 3.4 Forecast Demand and Inventory Control

Forecasting is important and essential to most operational activities. It is a valuable tool in calibrating the decision-making process, or to plan for upcoming business activity, or to estimate the resources that would be needed. There are different forecasting techniques. One of the simple classifications is historical forecasting, that is, using historical data to create predictions for the future. Other ways are intrinsic forecasting, extrinsic forecasting, and qualitative and quantitative figures.

Historical forecasting forms the basis of most inventory forecasting since it includes sufficient information and demand for products which changes continuously. The disadvantage of the historical forecast can be avoided with a predictive forecast, which is incorporating the understanding of future changes in addition to understanding what has already happened. The problem of predictive forecasting is a qualitative problem, for example, after launching a sales campaign, how to keep track of the demand increasing is one of that. In general, qualitative prediction is useful, yet quantitative method is necessary as well. (Wild, 2002)

### 3.4.1 Forecast based on Time

Regarding forecasts based on time, according to Lewis (1997), it is commonly accepted that short-term forecasting is associated with data from a week up to a month. Often, short-term forecasts are concerned with numerous product lines and items in more granular details of the inventory control environment. Meanwhile, medium-term forecasts are associated with more complicated calculations such as curve fitting and regression, Bayesian forecasting, and Fourier analysis, for a period from a month to a year.

The forecast horizon concerns the time periods ahead of the known facts and data. Generally, six periods ahead are the maximum forecast horizon, unless there is strong seasonal influence expected, i.e., the confidence level of the forecasts can be low if the forecast is too further ahead (Lewis 1997). The effectiveness of inventory control can be achieved by enhancing the integration between inventory control systems and different customer demand patterns. These details can be acquired from forecast data as well. Thus, to define the scope of inventory control application associated with the inventory model, it is important to study the correlation between forecast data and inventory planning.

### 3.4.2 Forecast based on Stock Control

There are different types of inventory forecasts that the companies can apply for different purposes. Theoretically, Wild (2002) stated that there are five practical and useful methods applied to stock control. Yet it is vital to choose the right forecast techniques for each product or group of products.

The first method is market research. It is possible to gain estimates of demand through customers' orders, and it is even better when customers already commit to those orders. Moreover, a trustful relationship with the biggest customers or biggest clients of A-class items can impose a crucial impact on forecasting accuracy. Another method of getting the market signals is to ask the salespeople. Since salespeople are sometimes confused between maximum potential sales and expected average sales, their input needs to be interpreted before use. Yet, it is more important to base forecasts on demand statistics and accurate data than sales information. Secondly, market demand models can be used based on knowledge of the market. The equation of the models can include major factors such as financial, technical, or commercial factors. Models will be more effective with leading indicators and simulations to develop tracking parameters. The third way is to use historical data techniques. Except for new products/ product lines and products with causal links to another forecast, forecasts can be based on historical data which can then be altered with other impacts. The fourth way is the minimum stock level issues. Often, it is used for checking the reorder level instead of only keeping the minimum stock. Yet, maintaining a stock level with a broad range of stock items is a big task and the increase in stockholding should be avoided. Thus, proper safety stock levels should be recalculated on a regular basis. Concisely, improving stock control has been an improvement in this forecasting technique. (Wild, 2002)

### 3.4.3 Forecast as a Join Activity

Forecasting is an effort that requires many teams and departments to involve directly or indirectly. Forecast's input should always include collected information from sales and marketers who know better than anyone about what is going on in the marketplace. Forecaster also needs to talk with production people who can explain operational constraints, or finance staff who concerns budget and other financial issues. In the genuine sense, forecast is the result of joined effort, and by lessen forecasting error even with an exceedingly small amount, it could help to increase revenue and therefore profits-significantly (Institute of Business Forecasting & Planning – IBF 2023).

The problem of using sales information rather than demand number is pointed out by Wild T. (2002, p.159) that the "actual amount issued does not correspond with the amount ordered." To be specific, many companies' records focus on "sales," yet professional stock control should monitor "demand" rather than the sales numbers. This is because the sales teams have the incentive to use forecasts as motivators to exaggerate optimism or to ensure the availability of stock. In another scenario, if sales performance is monitored based on achieving sales quotas, sales forecast number has a tendency inclining to under-forecast (Institute of Business Forecasting and Planning – IBF 2023). Thus, to correct the input data, sales data needs to be interpreted or the sales departments ought to be more attentive to the accuracy of their forecast.

## 3.5 The role of Data Management Platform

This literature review explores the challenges arising from the absence of a common data management platform in Internet of Things application companies and proposes potential solutions.

Gartner (2023) defines a data management platform as a software that controls the flow of data within an organization. Advanced data management platforms offer support for data transformation, sharing, analysis, visualization, and workflow optimization. These platforms contribute to workload reduction, time savings, and minimization of human errors in various business processes. Incorporating up-to-date software and leveraging analytics automation platforms are crucial steps towards harnessing the benefits of contemporary technology in this industry.

Efficient management of supply chain data plays a significant role in mitigating performance issues in the supply chain. By leveraging data and gaining insights, businesses can enhance inventory control processes, optimize stock levels, and develop effective inventory strategies. Therefore, choosing the right software and platform is essential as this decision influences the smoothness of workflow in the future. Organizations should consider factors such as the software's advanced features, security measures, and its potential for future development and adaptation. (Gopal, Rana, and Krishna, et al, 2022)

The absence of a common data management platform in IoT application gives rise to challenges such as data silos, incompatibility and interoperability issues, and concerns regarding data security and privacy. Data silos hinder collaboration and decision-making by preventing organizations from obtaining a comprehensive view of their operations. Incompatibility and interoperability challenges arise due to the lack of standardized data formats, protocols, and interfaces, making data sharing and analysis difficult. Moreover, without a common data management platform, ensuring data security and privacy becomes complex, increasing the risk of data breaches and unauthorized access. (Raptis, Passarella, and Conti, 2019)

To address these challenges, standardization is crucial. Developing and implementing standardized data formats, protocols, and interfaces facilitate seamless data integration and exchange. Additionally, establishing robust data governance frameworks and policies helps ensure data integrity, security, and compliance (Mahanti, 2021). Cloud-based data management platforms offer scalable and secure solutions, providing centralized storage, processing capabilities, and standardized application programming interfaces for efficient data sharing and collaboration. These platforms also enable advanced analytics and algorithms for deriving valuable insights from data.

In conclusion, the absence of a common data management platform in IoT industry presents significant challenges that impede the full realization of its potential. However, by adopting solutions such as standardization, data governance, and cloud-based platforms, organizations can overcome these challenges and unlock the benefits of a connected, data-driven industrial ecosystem. By addressing these issues, operational efficiency, collaboration, innovation, and competitiveness can be enhanced in the data industrial era. (Mahanti, 2021)

# 4 About the Inventory Model

The goal of this model is to provide re-order point from forecast number. Thus, it can empower inventory management managers to optimise forecast insights and plan for the inventory's upcoming activities in managing and ordering. Additionally, this model plays a part in making the effort of improving the system and the procedures of inventory management.

This theoretical part is based on the groundwork – The Silicon Lab Model – Optimising Silicon Labs' inventory strategy – Master Thesis of Barber, Simonsen, and Thomasen (2022) of Copenhagen Business School. Briefly, the groundwork presents an inventory model to determine when and how much to replenish Silicon Labs' inventory at the optimal level. Additionally, the groundwork introduces the re-order signal based on on-hand inventory in the new inventory replenishment system Based on this groundwork, the inventory model was built using forecast demand, standard cost and average sale price, and estimation of the replenishment lead time as the inputs to calculate reorder point. Thus, determining the re-order point means answering the question: "When the stock should be replenished?”. The two main components of reorder point are safety stock level and lead-time demand.

## 4.1 Model Inputs

There are several important inputs in this model to compute the re-order point, including forecast demand data, standard cost and average sale price, and replenishment lead time.

### 4.1.1 Forecast Demand Data

The thesis does not include the analysis of model input. Yet, a brief overview of forecast demand process is introduced in this section.

Forecast demand for inventory is updated monthly and quarterly. The process of determining forecast numbers involves input from many parties including customers, the sales team, and the marketing team (Wild, 2002). The techniques of forecasting vary from predictive analysis to extrinsic approach. Data is always interpreted by the data analytics team before putting into use. One of the goals of the new forecast model outcome is to get as close as possible to the balance point between the highest customer satisfaction level, which is inventory available level, and optimal margin/profit result, which is the optimal cost of inventory (Shinhar, N., personal communication, December 2022).

### 4.1.2 Standard Cost & Average Sale Price

Standard cost regards the fixed item value in financial transactions and is held the same for a certain period (Wild, 2002). The standard cost of products is typically used in manufacturing when justifying costs and overheads. In this study case, the standard cost is also recognised as a simplifying calculation for overstock cost.

On the other hand, understock cost is the margin or profit could have been gained from the sale of items that we did not have to satisfy demand. This is considered an abridged form of understock cost in this model. Due to the characteristic of the industry and product, the average sales price of each group of items is used instead of the individual item price.

### 4.1.3 Replenishment Lead-time

In one of the popular inventory control approaches, when on-hand inventory is less than or equal to the re-order point, an order to a supplier or a manufacturer to increase inventory level to the target level is issued. The lead time, the duration of time between the issue of the order and the receipt of the ordered items is referred to as replenishment lead time or supply lead time. Lead time is known to always have a certain rate of uncertainty and not a known constant parameter (Hung and Hsiao, 2013). Therefore, the average lead time of product groups is used to reduce uncertainty in general.

‘The semiconductor industry is characterized by long production lead times.’ (Kim, D., Park, Y.S., Kim, H.W., Park, K.S., Moon, I.K., 2022). Based on Kim et al (2022), the performance of inventory control and supply chain management depends significantly on lead time. Thus, with that characteristic of the industry, many companies are forced to hold myriad of WIP (work-in-process) inventory. With the case company, the author expected that the replenishment lead time of the model can be updated manually or ideally automatically through a data management system. The estimated lead time depends on the stages of inventory within the production line. Therefore, depending on different inventory types from the forecasts, the model ought to get different suitable lead-time to ensure all inputs are on the same page.

## 4.2 Model Process

A sequence of calculations using the inputs presented above to get to re-order point is demonstrated in this part of the thesis. The first step is calculating lead-time consumption. The second step is quantifying the customer service level. At last, safety stock is being calculated.

### 4.2.1 Leadtime Consumption

According to Prof. Bussom - Widener University, (2015), lead time consumption is the demand forecast during replenishment lead time ($LTD$). In other words, $LTD$ equals replenishment lead time $L$ multiplies by replenishment lead time demand $R$:

$$LTD = L * R$$

If the average demand $R$ is a variable, the mean of demand over lead time $L$ is used in this equation. If lead time $L$ is a variable, then the mean of the lead time is used.

### 4.2.2 Cycle Service Level ($CSL$)

Cycle service level, or service level, is the probability of not running out of stock in a certain period. In other words, it is the probability of available stock that satisfied customers' demand. By this logic, the amount of stock is less than or equal to the reorder point. At the same time, the service level is equal to a hundred percent minus the probability of stockout. (Prof. Bussom - Widener University, 2015)

Based on Chopra (2019), the optimal level of product availabilities and profits is calculated based on trade-off between overstocking and understocking cost. That said, at the optimal level, the profitable contribution of an extra stock unit is zero. Optimal $\mathrm{CSL}$ is calculated as:

$$CSL = 1/\,(1 + (C_O + C_U))$$

(With $C_O$ is Overstock cost and $C_U$ is Understock cost)

In other to applied normal standard deviation in the calculation, $\mathrm{CSL}$ is converted to $\mathrm{z}$ value ($\mathrm{z\ score}$) using the inverse of the normal distribution value of $\mathrm{CSL}$. In Excel, $z$ can be calculated as:

$$z = NORMSINV(CSL)$$

In addition, to convert $\mathrm{z\text{-}score}$ back to $\mathrm{CSL}$, in Excel, $\mathrm{CSL}$ can be calculated using the formular:

$$CSL = NORMSDIST(z)$$

### 4.2.3 Safety Stock

The surplus inventory, which is maintained beyond expected usage levels, serves as safety stock. Safety stock exists primarily to prevent the possibility of stock out. Therefore, safety stock is helpful in situations where demand increases suddenly or where supply failure, production shortfall, slow or unreliable information, and any other reasons lead to disruption of service (Wild 2002).

At times, lead time may vary, while in other cases, the lead time is fixed, yet the demand within that period remains uncertain. In all cases, the calculation of the standard deviation of demand during lead time is necessary. The standard deviation of demand represents the variation in demand forecast. When calculating safety stock, it is considered an assumption that replenishment lead time can be represented by normal distribution using average (mean) value (Prof. Bussom - Widener University, 2015). Normal standard deviation is represented by the standard bell curve area, where the centre line of the bell curve represents lead time demand (See fig. 4 for illustration). By subtracting the probability of $\mathrm{CSL}$ from the model gives the probability of the stock out during the re-order lead time.

Briefly, the formula for calculating safety stock includes the mean of lead time demand, its standard deviation from the mean, and $\mathrm{CSL}$ (see Figure 4 for illustration). To be exact, safety stock equals the number of standard deviations of stock above the median of replenishment lead time $(\sigma_{LTD})$ multiplied by the inverse normal distribution number of $\mathrm{CSL}$ $(z\ score)$. (Prof. Bussom - Widener University, 2015)

*Safety stock* = *z* *$\sigma_{LTD}$

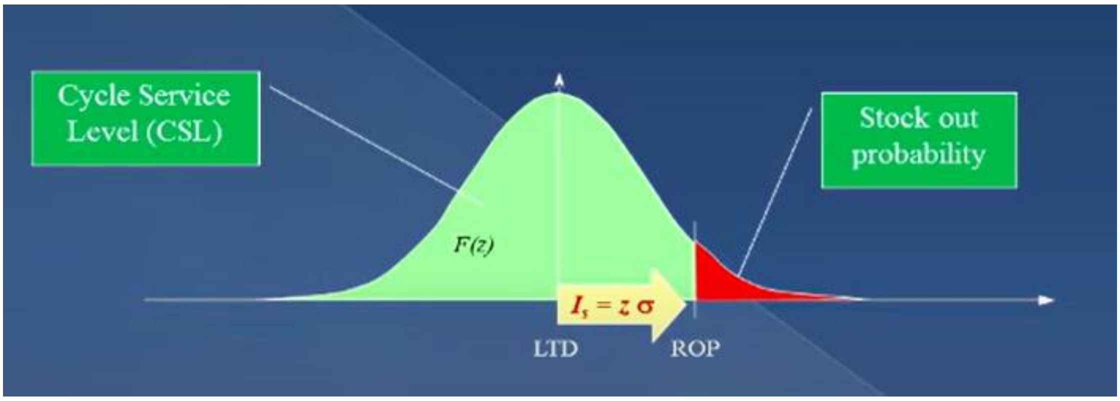


Figure 4 Standard deviation bell curve of lead time demand (Source: Prof. Bussom - Widener University 2015)

When demand is a variable, the formula for the standard deviation of demand during the lead time is calculated as:

$$\sigma_{LTD} = \sqrt{L} * \sigma_R$$

(With $\sigma_{LTD}$ is replenishment lead time; L is lead-time; $\sigma_R$ is standard deviation of demand.)

When demand and lead time are variables, the mean of demand and standard deviation of demand during the lead time should be calculated as:

$$\sigma_{LTD} = \sqrt{(L\sigma_R^2 + R^2\sigma_L^2)}$$

With $\sigma_{LTD}$ is standard deviation of replenishment lead time; L is lead-time; $\sigma_L$ is standard deviation of lead time; R is demand and $\sigma_R$ is standard deviation of demand. (Prof. Bussom - Widener University, 2015)

## 4.3 Model Output

The output of the model is recommended reorder point (see Figure 5 for illustration). The logic of reorder point is that when the level of stock on hand is equal to or less than the reorder point number, the replenishment order is triggered. ROP number is measured as the sum of safety stock and replenishment lead time demand (lead time average consumption).

$$\mathrm{ROP} = \mathrm{LTD} + \mathrm{Safety\ Stocks}$$

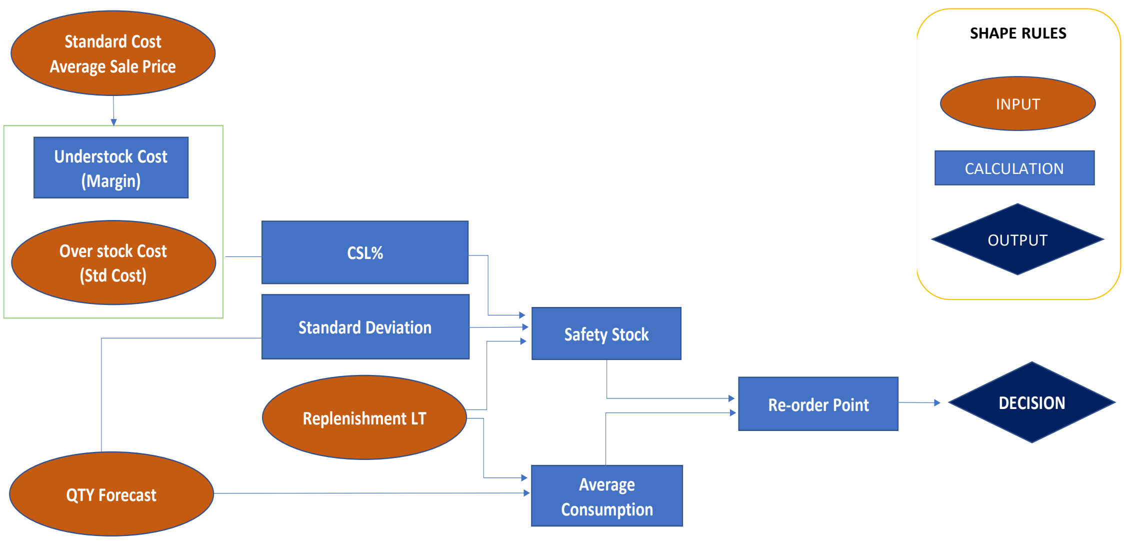


Figure 5 The model diagram (Source: Author 2023)

Additionally, the implementation plan in this case can be execute using the data management and analysis platform. Firstly, by following the theoretical strategic plan to execute key actions and accomplish the shared goal, answering questions on who, what, why, and how in detail, the project team can ensure the success of the project while minimising loss of time, conflicts of interest, and other risk factors. Secondly, after conducting the common goals and getting related parties on the same page, the very next step of the implementation plan is to map out the tasks, milestones, timelines, and risks. Next, it involves task assignment and resource allocation to the respective personnel. Finally, analysing the metrics and key performance indicators to evaluate the results is the last step of the project cycle.

# 5 Findings and Analysis

## 5.1 Summary of the Study

After studying the case company inventory forecast and planning process, together with the data analytics team, the author constructed the re-order point model based on the groundwork of Barber, Simonsen, and Thomasen (2022). The model presented in this report adopts vital elements from the reference model such as optimal calculation of re-order point, yet simpler since re-order quantity stage is not included. Moreover, lead time features of the case company forecast, and inventory planning process was taken into consideration. The model was first built and run with Excel. Then it was converted into Power BI platform. The idea of this step was to elevate the usage of forecast data at this initial stage and supporting decision maker in optimizing inventory planning.

To elaborate about the working process, the author had discussions with data operation team member, who oversees interpreting forecast data process, to comprehend how the data has been processed. Afterward, the author determined the necessary data to collect and how to extract insight from it. Moreover, the author had conversations with product planning manager and business analyst who works closely with demand planning process to understand case company inventory management process. The discussion includes how buffer target stock was determined and what signals drove the inventory decisions. On top of that, the author learned how the system was run as well as the difficulties the team deals with. Hence, the author collaborated with data analytic personnel to build the model in Excel using available historical data.

Additionally, to grasp how the model could extend to different cross-functional teams, the author opted to engage with teams that regularly cooperate, including data analysts, data governance, operations, and data architecture team. The author collected feedback on how this model can aid their functions.

Concerning the data architecture and governance team, this model does not provide additional value since they are not directly engaged in inventory management. However, they play a pivotal role in ensuring the efficient implementation of this new model. Discussing with them helped the author understand the holistic functions of the teams and getting the technical inputs in implementing the model. The author decided that the biggest value for this model is for the operations team and data analyst team.

Regarding collaboration with the operations team, the author engaged with several individuals directly involved in inventory management and forecasting. They are product planning manager, business operation analyst, and sales operations director of the case company. The discussion revolved around how inventory was managed at the time being, what disadvantages current system and software had, and what problems the new inventory model using unifying data management platform could solve. In summary, the inventory optimization recommendations from the model can help identify additional stock to support small and medium-sized customers within the system.

## 5.2 The Result of Model Simulation

The model findings reveal a consistent trend in product demand cycles. Typically, demand for older product models rises, reaches a peak, and subsequently declines, as they are gradually superseded by newer products. As the safety stock outcomes of this model rely on inventory optimization for profitability, its insights can guide decisions on stocking certain items more heavily while reducing stock in others, aiming to maximize revenue in inventory planning.

In this case study, the inventory model is crafted to yield results that prioritize optimizing the inventory's value while meeting the specified level of customer demand. As the simulation data shown in figures 4 and 5, depending on the unit cost and the average sale price of each product item, the cycle service level varies from less than 50% to as close as possible to 100%. Yet $CSL$ is just a by-product of the process since all customers' demands will eventually be satisfied after a certain number of replenishment cycles. According to Chopra (2019), at optimal $CSL$, the marginal contribution of reordering an additional unit is zero; moreover, the optimal CSL indicates the possibility that demand within the period will be at or fall below the corresponding optimal order. Hence, the model strives to optimize the inventory strategy outcome regarding the achieved revenue level per unit inventory cost.

On the other hand, replenishment lead time is the input that can be manually added or automatically updated by data management software. The more accurate the lead time, the better the outcome of this calculation. By using the average forecast demand during the estimated replenishment lead-time, the model was able to follow up with changes in the demand forecast during replenishment lead-time and reduce the sudden ramp-ups and plummets of up-coming orders. Considering the above feature, one could argue that the model's outcome is up-to-date simultaneously.

The graph below (Figure 6) showcases how ROP outcome looks like, providing that replenishment lead time is one and a half quarter. As indicated, the yellow line represents ROP suggestion, which has been able to cover enough demand unit plus suggested safety stock based on $CSL$ calculation throughout the time.

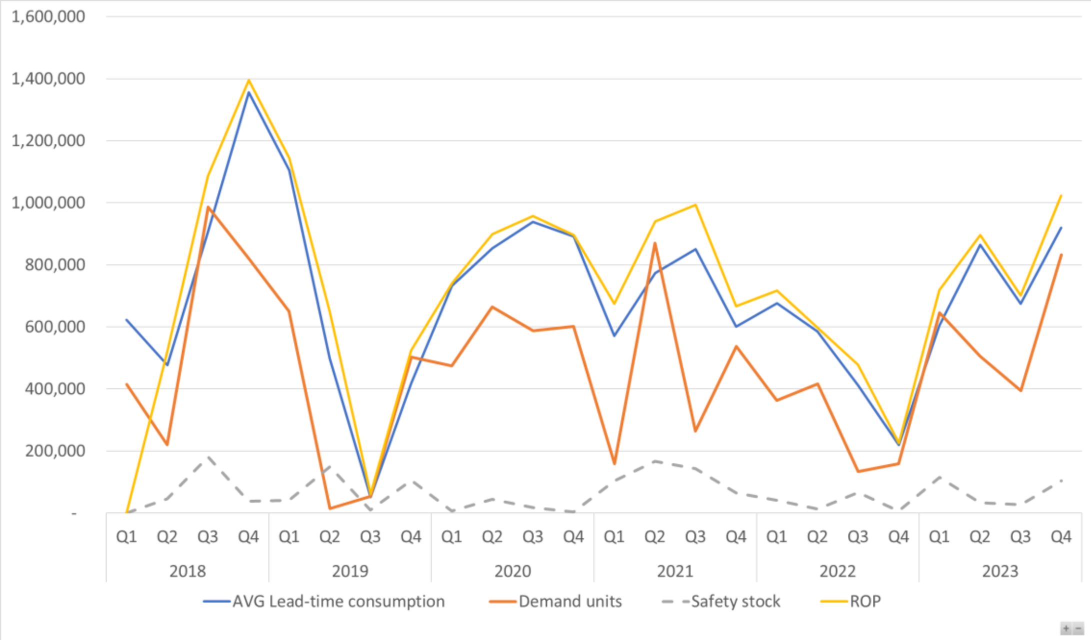


Figure 6 ROP planning outcome of scenario 1 (Author's source)

In a different situation, supposed that replenishment lead time is shorten to only half of a quarter, all other factors are remained the same, suggested ROP happens when inventory is just enough to cover demand in the upcoming half a quarter plus precalculated safety stock (see Figure 7 for demonstration).

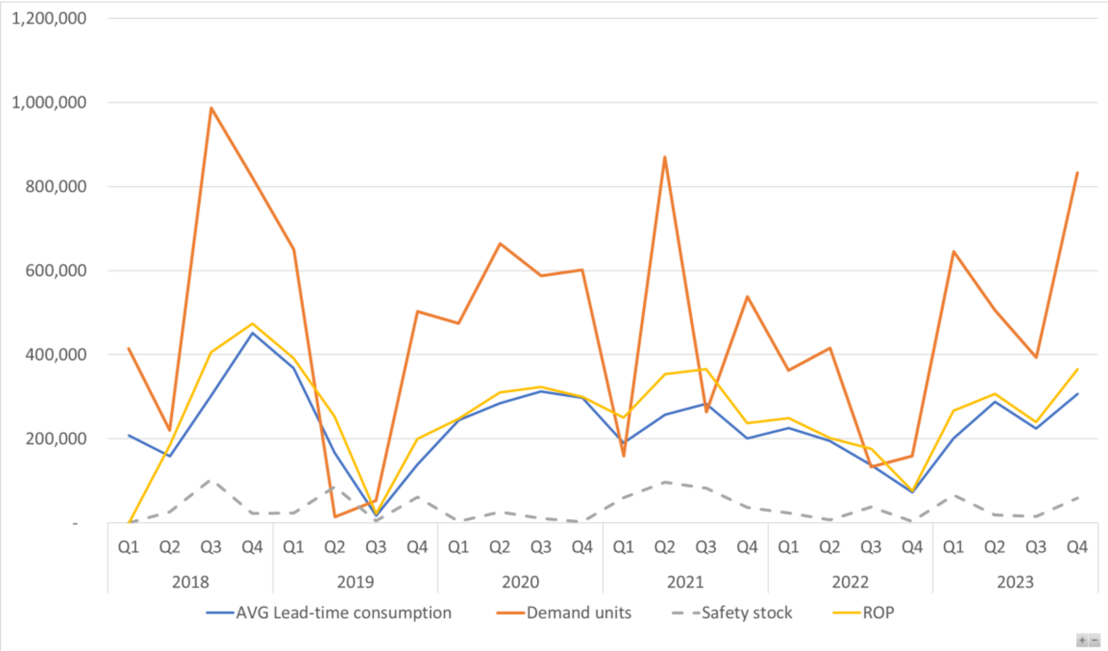


Figure 7 ROP planning outcome of scenario 2 (Author's source)

## 5.3 Implementation with Data Management Platform

To plot the technical part of the implementation plan, the author discussed with data architecture personnel to plan out the process of integrating this model into dynamic data visualisation platform.

The input of the model includes forecast data, which is updated monthly, quarterly, and yearly, the replenishment lead time can change on a weekly basis, which can lead to an excessive amount of manual work in updating the information and the speed of the service. Thus, using Excel as a tool is merely a temporary solution.

On the one hand, Tableau is not the best tool to use for model output illustration since it does not support direct complicated calculation such as Inverse Normal Standard Deviation. On the other hand, sine the model is in Excel format, one of the potential data visualisation platforms one can think of is Power BI of Microsoft. Power BI has a tight integration with Excel and other Microsoft software for pre-built and customise data visualisation. Mostly, Power BI is friendly with the Microsoft operating system and users who are familiar with Excel and other MS Office tools. Even though Power BI is not the only option for data visualisation, it is the optimal way of dynamically visualising output of this model.

The key component of successful implementation plan is having a suitable data management platform to connect all the data sources together and automate the data updating process. One of the suggested automation solutions is Alteryx. This tool provides the ability to combine different data sources, advanced data extraction, transformation, and consolidating different data into one source (Alteryx 2023). As Alteryx itself is a data transformational platform. It allows user to design the data transformation process without the need for writing complex script or programming with coding language.

Using Alteryx or any other innovation data platform such as Seeq, LITMUS, Altair, to name a few, can create workflows that automate the data preparation process and update the data for future use and exploration (see figure 8 for illustration).

These features are precisely what this case demands. Additionally, they save time and boost efficiency by leveraging real-time and updated data. The outcomes of the data are visualised by tools such as Tableau or Power BI. Furthermore, if data science and big data management become standard in this setting, the capability to facilitate predictive analytics and other advanced data science functions becomes essential.

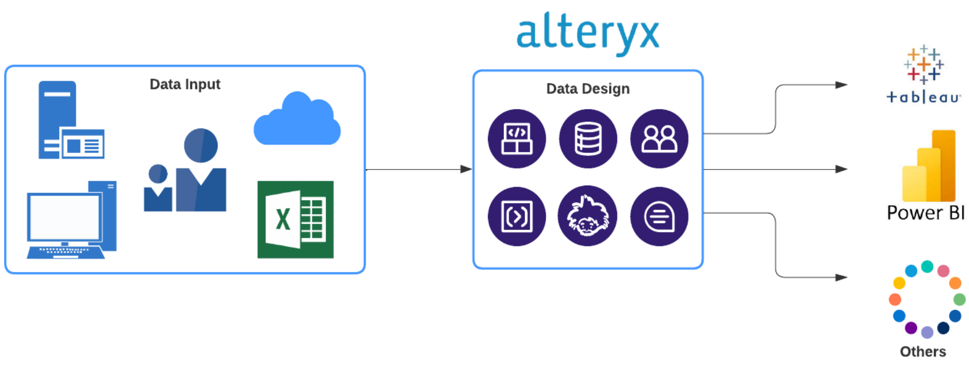


Figure 8 Data Design with Alteryx (Author's source)

However, one may suggest using Power BI for data visualisation directly without an intermediate agent like Alteryx. Yet Power BI could come with disadvantages if the team were not familiar with the tool. Besides, the disunity in data management tools and platforms can create obstacles and slow down the workflow when the project involves more team members and departments. If other inventory data is visualised in another platform, it could create frustration if one wanted to do some direct calculation and comparison using all available data at the same time.

## 5.4 Actionable Plans

Since re-order point and re-order quantity play the key role in inventory management, the author presented two sets of parallel actions, one was to assess the re-order point and apply it in real life, and the other one was to continue with the project of enhancing inventory management.

### 5.4.1 Implementing Re-Order Point

The first set of the action plan is to put re-order point calculation in implementation. By integrating the model into the current data management platform, users can find it easier to navigate, and assess the suggestion re-order with their original plan, resulting in a better decision. In the context when the case company is promoting lean management, enhancing data infrastructure, and automation process for business intelligence analysis, the implementation of this model in using new re-order point can be built easier thanks to the benefits of this process. As suggested in the previous part, one of the solutions is to use an advanced data analytics management platform, a cloud-based data analytics platform such as Alteryx. This helps create a platform manage all data within a centralise database management, which the capability to connect to any software has application programming interfaces (APIs).

The second step is to train the employees. For the best outcome of the model, it is ideal to cooperate with Data Governance team or Data Steward Team to set up the training process and documented it for future reference and to ensure efficient performance.

The third step in this first action plan is to regularly monitor the results using established measurements and KPIs. The set of measurements should include metrics for user satisfaction as well as for the inventory management metric systems.

### 5.4.2 Determine and Implement Re-Order Quantities

The second set of the action plan is to further develop this strategy to get to re-order quantity. This phase will bring an opportunity for higher level of collaboration within sales and operations planning teams (see Figure 9 for displaying).

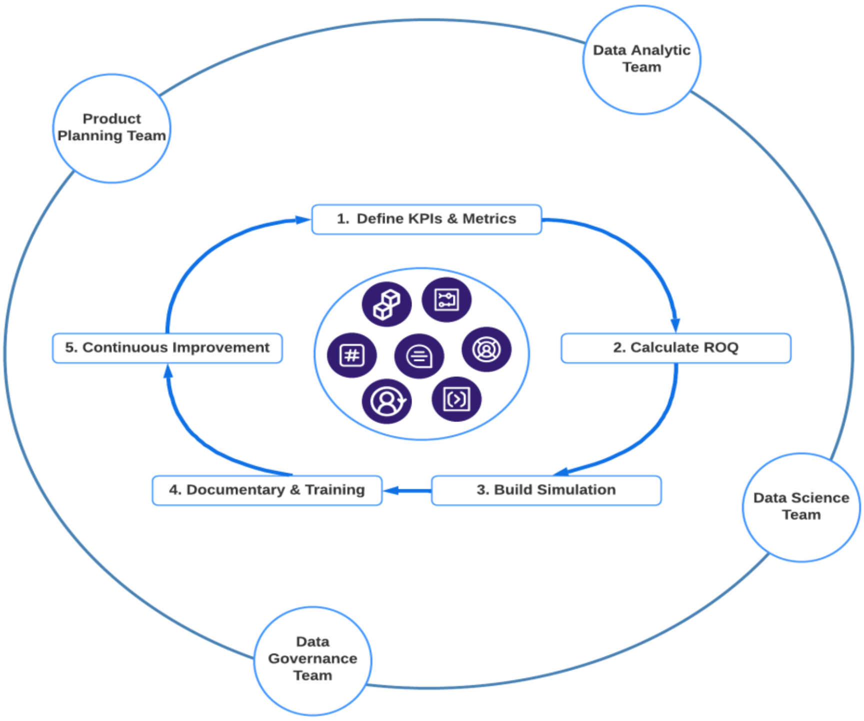


Figure 9 Re-order Quantities Process Chart (Author's Source).

In this case, due to safety stock has been calculated, what needed to be done is decided the desired order number for the next inventory cycle to get to re-order quantities. Hence, the first step of this set of action is to collaborate with the product planning team to define suitable KPIs and metrics to measure the effectiveness of the new re-order quantities,

The second step is to set up a suitable way of calculating re-order quantities. Calculating re-order quantities involves considering several factors such as consumption rate, supplier lead-time, holding cost, order cost, etc. to get the desire outcome which is best inventory plan. Once the re-order quantity computation is defined, its outcome can be evaluated using historical data, metrics, and other KPIs to evaluate the performance.

The third step is to build simulation, calculating risks and setting up proper measurement system to test the model. It is important to get performance evaluation and adjustment during testing phase.

Once the model is approved as it can be used in real life, the fourth step is training users to use the model at the most efficient way, Like the previous set of actions, official document is necessary to secure the flow of the process.

Finally, continuous improvement is the core competency of any business. Thus, identifying and addressing flaws, inefficiencies of the process can be done regularly.

Data management platform can be used to create simulation with live data and supply a trustful environment for testing the re-order point and the re-order quantity strategy.

# 6 Limitations

Initially, regarding the selection of a data management platform, it is vital to learn the pros and cons of all the options in advance. When it comes to Alteryx, this application itself is a data transformational platform. As data transformational capabilities is the powerful features of Alteryx, it becomes the disadvantage point if company has the need for high-performance data processing such as Machine Learning. Because Alteryx does not design for heavy programming and machine learning support, or data modelling with multi-dimensional data.

Further to that, when it comes to adopting a new data management platform, there are several points must be addressed: (1) Adopting a new data platform requires a range of budget and a new process of managing the system. That includes resources involved with proper training for using the new tool and minimizing the mistakes. (2) It is vital to have an expert to taking care of the setting up process to deploy the new tool fully and properly. Since the exposure to unexpected technical risks is higher, especially at the starting stage. With an expert in the team, risk such as unexpected data integration affecting the integrity of the whole data can be avoided. (3) The limitations on scalability would become an issue in the future due to the myriad of data that is produced and stored every moment. Besides, it is vital to make sure the software technology is on par with the development of the business from time to time. (4) Employing new data platform introduces risk for data security, especially when businesses rely increasingly on critical data. The need for properly configured and regulated data is necessary, including managing vulnerabilities related to the software itself, and other issues such as data breaches and cyber-attacks.

# 7 Conclusion

Key logistics activities involve the very first step of taking care of customer service to support demand forecasting and planning, purchasing, procurement, inventory management, etc. The better the logistic system, the more competitive the enterprise performs in the market. The inefficiency of supply chain can occur because of a conflict of interest, distorted, delayed information flow between stages, or inefficiency of incomparable information sharing. Each stage of the chain focuses on different goals and handles by different teams. Since the accuracy of the inputs is vital to the precise level of the model’s outcome, working with the simulation inventory model will stimulates and encourages cooperation and the thrive for accurate inputs of all related team for replenishment time, forecast demand, cost, to name a few. In addition, the simulation allows the management team to change the inputs and get the experiment outcome from different scenarios, to retrieve insight data and develop a better strategy.

The implementation of the inventory model involves a set of actions that needed to be done. Furthermore, the next step of developing the model is to generate recommendations for the re-order quantity, which can also be evaluated and analysed by building similar simulation model.

In summary, the presentation of how to roll out the model is suggested with a novel data platform. Moreover, the first action plan is raised with evaluation of potential risks and hindrances. In addition, suggestions for advancing the model to the next level are given with a high-level overview.

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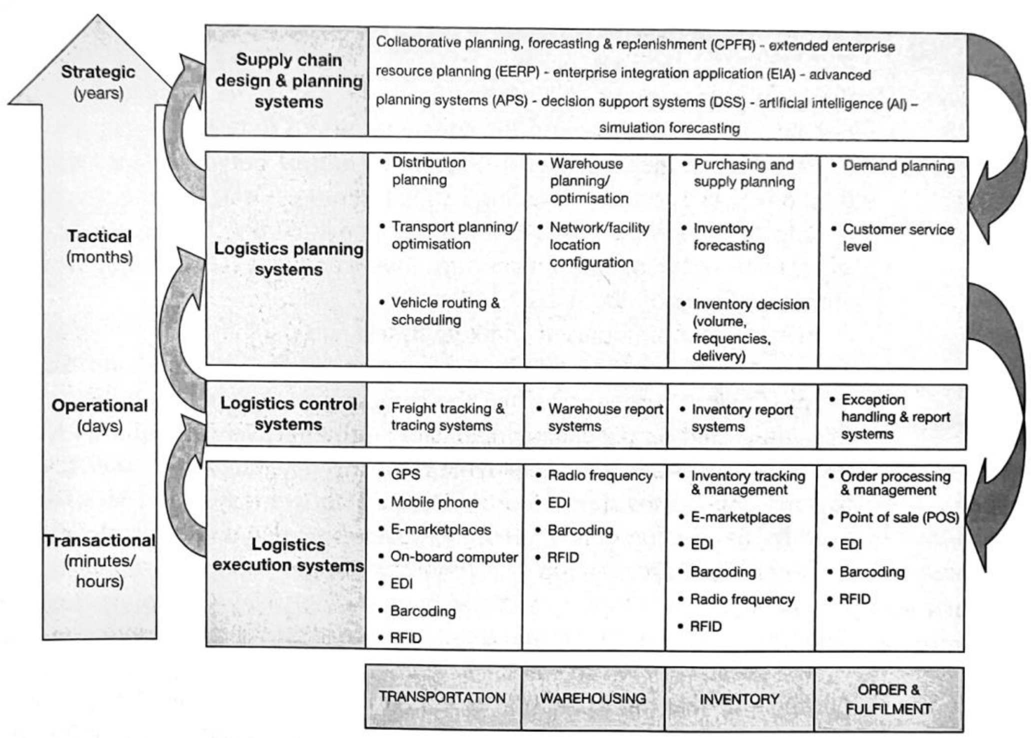
# Appendices

## Appendix 1: ICT systems and logistics applications




(Source: Evangelista cited in Grant and David, 2012:139)

Appendix 2: List of questions the author used to inquire information and acquire the overall vision of this project.

1. Addressed to the Project Lead:

   "What is the overarching goal or vision for this inventory planning project?"

2. Addressed to the Project Team:

   "Which departments bear the primary responsibility for this project and which departments are involved?

   How this new project connects with your current responsibilities or tasks?"

3. Addressed to the Forecast Demand Specialist:

   "What methods do you currently use to forecast demand, and what challenges are you facing in this process?"

4. Addressed to the Production Lead:

   "What are significant challenges you are facing in the realm of inventory planning?"

5. Addressed to the Customer Account Manager:

   "As you execute your responsibilities, what significant challenges do you face concerning inventory planning?

   What improvements do you expect the new inventory project could bring to effectively meet customer demand?"