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Optimizing inventory management in the insulation manufacturing industry

Herbert-Hansen, Zaza Nadja Lee; Larsen, Samuel Brüning

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Zaza Nadja Lee Hansen (znlh@dtu.dk)
The Technical University of Denmark
Engineering Management, Operations Management section

Samuel Larsen
The Technical University of Denmark
Engineering Management, Operations Management section

Abstract

Inventory issues within the insulation manufacturing industry are essential for competitiveness. However, they are largely unexplored in academic literature. Therefore the aim of this paper is to address the research question: "What approach to inventory management provides the best balance between service level and cost for the insulation manufacturing industry?" This is done through an in-depth case study of a world-leading company within this industry, with focus on two of its factories. This paper contributes with empirical research within operations management in a sector which has not been well-researched and presents results which are useful for both practitioners and academics.

Keywords: Case study, Insulation manufacturing industry, Inventory management

Introduction
Increased competition has resulted in quick delivery expectations and a need for a larger assortment of products. In this context inventory management plays an important role. This paper defines inventory management as "the process of managing and controlling raw materials, work-in-progress and finished goods inventory". In the insulation material industry inventory management is essential for competitiveness due to the large physical composition and low density of products, low costs of customers substituting products, quick delivery expectations, and high service levels resulting in high storage and transportation costs. Set-up costs are very high in the industry resulting in a need for levelled production outputs, which further adds to storage costs. In short, this industry has been struggling to meet customers' need for fast delivery without the burden of large and expensive inventory investments.

While inventory issues within this industry are essential for competitiveness, they are largely unexplored in academic literature. Therefore, the aim of this paper is to address the following research question: "What approach to inventory management provides the best balance between service level and cost for the insulation manufacturing industry?"

Methodology

Due to the explorative and complex nature of the research aim, this research uses a qualitative approach, as well as a quantitative approach, providing rich and in-depth data on the research area. Therefore the case-study approach was selected as the most appropriate research methodology (Yin, 1989; Oakley, 1999). The case organization was selected based on key parameters including, (i) an insulation manufacturer with a global supply chain, (ii) large inventories around the world, (iii) the company expressing a need for an inventory strategy reconsideration and (iv) access to a substantial amount of quantitative data from the business warehouse and direct access to interview partners in appropriate as well as leading roles within the business.

The organization used for the case study has global production and sales units within the insulation manufacturing industry. The case company will be referred to as Insulation Inc. for the sake of anonymity and is one of the world's largest insulation manufactures. The company has production and sales offices all over the world, including Europe, Russia, North America and Asia, reaching revenues in the billions EUR.

The study details two cases within the same case firm. These two cases originate from two separate factories, with each their respective warehouses, located in Germany and in Poland. They will be referred to as G-Insulation and P-Insulation. They were picked due to the fact that they were the largest factories in terms of operational stock.

Data from the company was gathered by following an inventory strategy optimization project. The researcher team was present in the company's headquarters on a daily basis and for the gathering of specific quantitative and qualitative data several of the European Operating Companies was visited. The project was concluded in June 2015. Data was collected through interviews and company documents. Furthermore, quantitative data was gathered from the company's ERP system for financial information as well as data relating to customer orders, inventory expenses and a general overview of current costs and profit margins.

This method ensured accurate representation and enabled triangulation of the findings between different sources of information, thereby improving validity. In this manner the project ensured a high level of industry relevance and involvement while focusing on utilizing key theories within this research area.

Literature Review

Felea (2008) identified that inventory, together with transport and the location of the production and the storage, as the main contributors that affect the performance and efficiency of the supply chain. Waller & Esper (2014) came to a similar conclusion, and specified that inventory is a fundamental measure of the overall efficiency of supply chains. Emmet & Granville (2007) summarizes the reasons for holding inventory as a way to enhance the balance between supply and demand to provide service to customers, improve forecasting and to reduce waiting time and material flow time.

If the time of the supply is a known element and demand is relatively stable, it defeats the necessity for protection against stock-outs, neither is forecasting of the demand required, and the time of reordering can be categorized as the point where the amount of inventory will satisfy the given demand until the ordered quantity arrives in stock (Waller & Esper, 2014). However, with global competition, quick product development and extreme product customization, it complicates the prediction of demand and planning for the necessary production and inventory levels (Fisher *et al.*, 1994). Hence, supply chain managers and their teams need to identify the main

strategies of inventory management and design their framework in a way that can be dimensioned as needed.

A significant percentage of assets held by companies throughout many different industries can be accounted to inventories. Therefore, one of the crucial features in the improvement of a firm's working capital and its return on assets relies on the successful management of the firm's inventories (Freeland *et al.,* 2009). For the appropriate inventory management in a supply chain with capacity constraints, it is of great importance that the company uses the correct replenishment methods, and that the parameters within the methods are set accordingly (Grewal, *et al.,* 2014). Inventory replenishment methods deal with two of the most central decisions of inventory management; when should an order be initiated and how much should be ordered (Emmet & Granville, 2007). Waller & Esper (2014) claims that there are two main components to consider when choosing the inventory replenishment methods:

- Should the product undergo a continuous review or should it be reviewed periodically?
- Should the levels of inventory be discrete or should they be continuous?

Within the continuous inventory method and the periodic review method, the main methods that will be looked into are the Reorder point (ROP) method with fixed reorder quantities (Q, ROP) or (Q, r) methods where Order quantity is designated Q, and the review period (T) Order up-to level (OUL) method (T, OUL). This is due to the characteristics for this industry as described in the introduction and the demand distribution.

Findings

The forecasted capacity utilization for 2015 compared with 2014 for the European facilities of Insulation Inc. is shown in figure 1. Sales are expected to increase by 4% from 2014. With that in mind, capacity utilization is expected to reach maximum all over Europe, except for the Christmas season. The only exception is one facility (the dotted line), where the factory still has 15.000 tons of manufacturing capacity available in January throughout April.

Figure 1 - Forecasted Capacity Utilization 2015
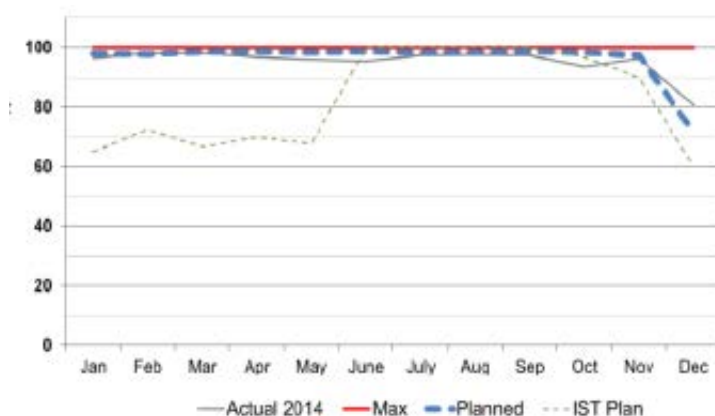
The two factories in scope for this investigation, G-Insulation and P-Insulation, had some similarities and some differences as can be seen from the table below.

	G-Insulation	P-Insulation
Customer lead times	- A products: 48-72 hours - B products: 3-5 days - C products: Individual agreement (around 1 week)	- A products: 48 Hour - B products: 10 days - C products: Individual agreement
Production planning	- Daily planning on daily basis	- Weekly planning on daily basis
Batch sizes	- Short batches - Frequent changeovers (Min 12 times a day)	- Long batches (Specially for A products) - Not a lot of changeovers a day
Inventory system/ methods	- No MRP run - Sales forecasting - The planners check inventory levels of products needed and order to production manually: excel spreadsheets - Products and amounts of products put on stock based on planners experience	- MRP run - Sales forecasting - The planners check inventory levels of products needed and order to production manually: excel spreadsheets - Amount of inventory based on ABC classification A products: 2 weeks inventory B products: 1 week inventory C products: No inventory
Inventory control	- No safety stocks - No reordering points - Minimum inventory levels considered by planners experience	- Safety stock only in some semi products - No reordering points

Table 1 - Comparison between key production matrixes in G-Insulation & P-Insulation

The biggest difference between the two factories is that G-Insulation is doing the production planning daily and P-Insulation is doing it weekly. This indicates that G-Insulation is having shorter but more frequent batches while P-Insulation creates longer batches. A common feature is that both countries are checking orders and planning inventory manually at the SKU level, spending a lot of resources on this process. Furthermore, the large amount of manual data can lead to mistakes, and inefficiencies.

In connection with inventory control, both countries are similar since they do not have any best practice inventory method established. As a consequence, they do not work with safety stocks, reordering points or economic order quantities. They plan inventory by subtracting order quantities or forecasted order quantities from the current inventory levels, and order the difference by the production department.

In addition, both facilities made use of ABC classification methods for the structuring of the inventory portfolio. However, the basis of the classification approach was significantly different. In P-Insulation the generated net sales of a product constituted the base of the classification, whereas G-Insulation considered the order frequencies. Both lacked a theoretical acknowledged inventory management strategy, resulting in complex and costly inventories. A double ABC analysis was used in this project and the result of it could be used to assign different service levels to the different classification groups. Combining this analysis with a demand pattern classification, it was possible to describe which products should be make-to-stock and make-to-order based on their value and which customers bought them (see for example Wilson & Perumal (2010) and Fisher & Vaidyanathan (2012) for strategies relating to ABC analyses).

After a thorough collection and compilation of data a MS Excel tool was specifically developed for inventory managerial purposes for Insulation Inc. to process the results from the dataset. The tool has a discrete event simulation approach which was chosen to be an easy and reliable method for the simulation of inventory processes (Waller and Esper, 2014). Apart from being a simulation tool, the tool contains functionalities making it possible to act as an inventory planning tool later on. Five different inventory management approaches were tested using this simulation tool for all product groups and product classifications:

- Order quantity (Q) + Re-order point (ROP) (M1)
- Review period (T) + Order up-to level (OUL) with Normal distribution (M2)
- T + OUL with Gamma distribution (due to erratic demand) (M3)
- OUL + ROP with Gamma distribution (due to erratic demand) (M4)
- OUL + ROP with Normal distribution (M5)

The two main inventory replenishment methods tested were Order quantity (Q) + Re-order point (ROP) and Review Period (T) + Order up-to level (OUL) methods. The first method utilizes a normal distribution for the safety stock calculations. The second main method taken into account whether the products have a stable or non-stable demand resulting in two methods; one with normal distribution and one with gamma distribution. The two main inventory replenishment methods (Q + ROP) and (T + OUL) were combined in a hybrid method (OUL + ROP) as described by (Waller & Esper, 2014), which utilizes the benefit of constant inventory monitoring and combines it with the benefit of variable order quantities.

The five methods represent different inventory planning approaches and it is not unusual that a method performs with a lower average inventory over the year, but it is out of stock more often than another method with higher inventory levels. Due to this, an additional evaluation method is required. The Multi Criteria Decision Analysis (MCDA) is used for this purpose. The goal is to reach a potential best inventory method for each specific Stock Keeping Unit (SKU).

For the MCDA, three criteria are taken into account: Stock-out quantities **(C1),** Average inventory **(C2)** and Times out of stock **(C3).** These were selected due to the characteristics for this industry described in the introduction. For example, as set-up costs were large for all products it was not a useful decision criteria. The specific method used for MCDA is REMBRANDT (Leleur, 2012). First, each criterion is given a weight using pair-wise comparison between each of them. This result is then put into a criteria comparison matrix with the strengths scored on a scale from 8 to -8 as shown in Table 2.

	C1	C2	C3
C1	0	4	2
C2	-4	0	-2
C3	-2	2	0

Table 2 - Criteria comparison matrix

There is a clear preference for times out of stock (C3) compared to average inventory (C2), a slight preference for times out of stock (C3) compared to stock-out quantities

(C1), as well as a slight preference for stock-out quantities (C1) compared to average inventory (C2).

The MCDA is coded in Excel so it automatically calculates the best method when running the simulation tool for a specific material number. Scores for each of the five methods under each criterion are calculated and the final scores for each method are calculated by multiplying all scores of each method under each criterion uplifted with the criteria weights (see table 3).

	M1	M2	M3	M4	M5
Score	0,435	0,123	6,434	0,888	3,281

Table 3 - Total REMBRANDT scores

The final results from the MCDA show that method 3 T + OUL with Gamma distribution (M3) has the highest score (see Table 3).

To test the superiority of M3 the simulation tool was used. The tool works using buttons and a dashboard which allows the user to review the performance of the different replenishment methods in a tabular and graphical way. The simulation tool is made up of 23 sheets, 20 of which are used for the actual simulation, two sheets are used for evaluating the results and one sheet display the most relevant results from the individual simulation runs.

The simulation tool automatically loads all the necessary parameters for the SKU. The parameters used are forecast, sales, ROP, Economic Order Quantity, Safety stock, Order Up-to Level and Review period. Each of the five replenishment methods is simulated for all SKUs. An example of the overview of results from the simulation tool can be viewed in Figure 2.

Figure 2 - Example of Excel Simulation Tool

The simulation tool has been used on material numbers within the A and B product classification, with both a stable and erratic demand pattern. Two simulations have been executed, one for P-Insulation and one for G-Insulation. These are described below.

The simulation results for P-Insulation
For P-Insulation there are 361 material numbers within the A and B product classification. 275 of these have been used for the simulation to determine the most optimal replenishment method for SKUs within a specific classification and using either a stable or erratic demand pattern. 86 material numbers have been excluded from the analysis due to their lack of data on previous inventory data. Additionally, for the ordering cost comparison, it has been necessary to exclude 138 of the 275 material numbers due to a lack of comparison data on the amount of product orders in P-Insulation.

P-Insulation Stable Demand	AA	AB	BA	BB	CA
Q, ROP	17%	0%	0%	100%	0%
OUL, ROP - Gamma	42%	0%	100%	0%	0%
OUL, ROP - Normal	36%	0%	0%	0%	0%
T, OUL - Normal	3%	0%	0%	0%	0%
T, OUL - Gamma	3%	0%	0%	0%	0%
Total	100%	0%	100%	100%	0%

Table 4 – Simulation results for SKUs with a stable demand pattern in P-Insulation

The results of the simulation show that for SKUs with a stable demand pattern the (OUL, ROP) method with a gamma distribution for calculating the safety stock is the best performing replenishment method for the A classified products (see Table 4). However, looking at the products in the B classification, the (Q, ROP) method is the far superior replenishment method (see table 5). Although it should be noted that the 100% score is only reached for a single material number out of 275.

P-Insulation Erratic Demand	AA	AB	BA	BB	CA
Q, ROP	8%	27%	29%	29%	33%
OUL, ROP - Gamma	59%	36%	21%	25%	0%
OUL, ROP - Normal	15%	9%	26%	38%	33%
T, OUL - Normal	14%	9%	16%	5%	0%
T, OUL - Gamma	5%	18%	8%	3%	33%
Total	100%	100%	100%	100%	100%

Table 5 – Simulation results for SKUs with an erratic demand pattern in P-Insulation

For products with an erratic demand pattern the (OUL, ROP) method utilizing a gamma distribution for calculating the safety stock is the best replenishment method with a 59% efficiency. Reviewing the products in the B classification, it can be concluded that the best replenishment method is the (OUL, ROP) method using a normal distribution for calculating the safety stock.

However, it is important to note, that the results shown above represent aggregated results. In order to get the most optimal result, it is necessary to define a replenishment method for the individual SKUs. Individual SKU replenishment methods will increase the inventories on some material numbers and decrease them on others and most importantly, reduce the total inventory and thus decrease the total inventory cost. This

simulation run results in an inventory increase up to 1.745 tons and inventory decrease up to 8.288 tons in P-Insulation. Additionally, the yearly production orders are increased by up to 426 orders for G- Insulation and decreased by up to 2.687 orders for P- Insulation.

Lastly, Table 6 summarizes the economic effects that the use of the newly designed inventory replenishment method could potentially have in P-Insulation. The table shows that the reduction of inventory yields potential savings of €952.593.

Average Holding Cost Increase	Average Holding Cost Decrease	Ordering Cost Increase	Ordering Cost Decrease	Final Saving
€423.490	€1.231.940	€53.748	€197.891	€952.593

Table 6 - Economic implications for P-Insulation by using the new inventory method

The simulation results for G-Insulation

For G-insulation there are 837 material numbers within the A and B product classifications. 22 of these lacked data for inventory levels and has been excluded from the simulation run, reducing the total material numbers used to 815. For the ordering cost comparison only 486 material numbers were eligible for the simulation due to a lack of data for the ordering cost.

The results of the simulation run show that for the SKUs with a stable demand pattern, the (OUL, ROP) replenishment method following a gamma distribution is the best performing method for both the products in the A and B classification (see table 7).

G-Insulation Stable Demand	AA	AB	BA	BB	CA
Q, ROP	26%	29%	13%	29%	0%
OUL, ROP - Gamma	37%	43%	50%	44%	43%
OUL, ROP - Normal	36%	29%	33%	27%	57%
T, OUL - Normal	0%	0%	2%	0%	0%
T, OUL - Gamma	1%	0%	2%	0%	0%
Total	100%	0%	100%	100%	100%

Table 7 – Simulation results for SKUs with a stable demand pattern in G-Insulation

For SKUs with an erratic demand pattern, the (OUL, ROP) replenishment method utilizing a gamma distribution is the best method for the products in the A and B classification (see table 8).

G-Insulation Erratic Demand	AA	AB	BA	BB	CA
Q, ROP	28%	25%	16%	38%	0%
OUL, ROP - Gamma	35%	35%	58%	40%	100%
OUL, ROP - Normal	35%	38%	26%	22%	0%
T, OUL – Normal	2%	0%	0%	0%	0%
T, OUL – Gamma	0%	2%	0%	0%	0%
Total	100%	0%	100%	100%	100%

Table 8 - Optimal replenishment methods for SKUs with an erratic demand pattern in G-Insulation

Results from the simulation run show an increase in inventory up to 2.995 tons, and an inventory decrease of up to 9.264 tons in G-Insulation. The yearly production orders increase to 3.478 orders and decrease to 7.817 orders.

Additionally, Table 9 shows the summarised economic effects that the use of the designed inventory replenishment method would have on G-Insulation. Inventory reduction could result in total savings of €2.037.351.

Average Holding Cost Increase	Average Holding Cost Decrease	Ordering Cost Increase	Ordering Cost Decrease	Final Saving
€840.690	€2.190.417	€204.737	€892.362	€2.037.352

Table 9 – Economic implications for G-Insulation by using the new inventory method

To summarize, in both P-Insulation and G-Insulation, the hybrid replenishment method (OUL, ROP) outperformed the other methods significantly.

Discussion

The simulation tool showed that the continuous review replenishment methods with variable order quantities were outperforming the other methods in almost all cases. It is most likely caused by the constant inventory monitoring and variable order quantities which makes the method more flexible. The added flexibility results in a significant reduction in both holding costs as well as in ordering costs. One of the main reasons that ordering costs decreased so much is that the orders suggested by the simulation tool are on a weekly basis; hence daily orders, like they often are done in the factories, are not possible. The reduction of the inventory could be caused by reduction of seasonal stock, which is not planned to the same extend as P-Insulation and G-Insulation is doing now. The simulation tool is planning the orders to shorten the gap between production and distribution, so that the products are held in inventory for a shorter period of time. However, it is believed that inventory could be reduced to a larger extent. In several cases, other methods than the one chosen by the simulation run were superior in the reduction of the average inventory. But at the same time inferior with respect to delivery performance.

If Out-of-Stock situations had been given a lower weight in the MCDA, results would have been significantly different. In the case of G-Insulation, it was found that the inventory reduction was considerably smaller when comparing to P-Insulation, whilst keeping the amount of material numbers analysed in both factories in mind. The analysis of inventory reduction was based on 186 material numbers in P-Insulation, whereas the analysis in G-Insulation was based on 486 material numbers. Although the amount of material numbers analysed in G-Insulation were 161% higher, the total inventory reduction was only 11,78% higher. It is assumed that the reason for this is that the production orders in G-Insulation are smaller, with lower average inventories, taking market size into account.

While these results are not generalizable and were never intended to be so, these results indicate that a thorough analysis of replenishment methods in the insulation manufacturing industry could help produce inventory management savings.

Conclusion

Inventory issues within the insulation manufacturing industry are essential for competitiveness, yet they are largely unexplored in academic literature. Therefore, the aim of this paper was to address the following research question: "What approach to

inventory management provides the best balance between service level and cost for the insulation manufacturing industry?"

This was addressed through an in-depth case study of a world-leading company in this industry, Insulation Inc. The investigation was focused on inventory planning practices in two insulation manufacturing factories owned by this company, P-Insulation and G-Insulation.

In order to provide a systematic replenishment strategy, five different inventory replenishment methods were tested using a developed Excel simulation tool for all product groups and product classifications, and the obtained results were compared with current practices by use of the Multi Criteria Decision Analysis technique.

Using the developed simulation tool the best results were obtained using the (OUL, ROP) – Gamma distribution method because this method gives a continuous review replenishment method with variable order quantities which uses constant monitoring and has the ability to adjust rapidly to sudden and large fluctuations in demand which can handle erratic demand. The superiority of the hybrid replenishment method was proven by comparing the performance in terms of delivered service and average stock levels.

The suggested approach to inventory management yields comprehensive inventory cost and complexity reductions in both case factories with a differentiated approach to service levels. In addition, the results provide a reduction of manual work in the planning approach while increasing efficiency and effectiveness.

The applicability of the approach was tested in the case company which means it can be expanded to other facilities within Insulation Inc. and likely also to other companies within this industry although further research is needed to test this.

This paper thereby contributes with empirical research within operations management in a sector which has not been well-researched and presents results which are useful for both practitioners and academics.

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