

# SAFETY STOCK PROVISION AMID FLUCTUATING DEMAND IN THE UK AUTOMOTIVE INDUSTRY

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## **1. Introduction**

Industry practitioners and academics have acknowledged the importance of achieving an efficient and effective Supply Chain (SC), therefore various initiatives and techniques have been developed in this area to improve SC Management (SCM). Within the automotive industry, customer preference is dynamic especially in the choice of features such as safety options, amenities etc. (Fine et al., 1996). This poses a challenge to the SC in terms of understanding and interpreting customer requirement to accurately order raw materials at the right quality and quantity. Limere et al., 2012, described the automotive industry as being characterised by fierce competition which makes suppliers/manufacturers to aim for competitive advantage by adapting their manufacturing processes and supply chain to respond to dynamic customer demand.

This challenge forms the focus of the research which aims to improve the materials planning and scheduling process of an assembly plant. To achieve the aim, the paper identifies a suitable and robust technique for providing safety stock for the materials planning process in an assembly plant which was validated and applied to a case study. The paper is structured thus; Section 2 provides SC background and discussion of inventory management techniques. Section 3 describes the research methodology, while section 4 provides approaches for safety stock provision. Section 5 presents an application of the best approach using a case study of three products while Section 6 presents the discussion and conclusion.

## **2. Background**

### **2.1. Supply chain management**

The SC is the network of organisations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in form of products and services in the hands of the ultimate consumer (Christopher, 2005). These activities include procurement, inbound logistics, outbound logistics, materials planning and operations. Materials management is particularly crucial in manufacturing and assembly plants. It includes the planning, procurement and acquisition of inventory or raw materials to support company operations. In manufacturing or assembly operations, inventory consists of components which are assembled or integrated together in order to deliver the final product (Greasley, 2009). The inventory management process of an automotive supplier is provided in the next section.

### **2.2. Automotive Inventory management Process**

**2.2.1 Customer Lead Time** – On a daily basis, minimum lead time for a regular set of products (seating system) is 4 to 6 hours from the time a customer requirement is sent, with a maximum requirement 10 hours, depending on the volume of customer broadcast window. The product building is done to sequence rather than 'build to stock'. The seating system is the supplier's finished product delivered to the customer organisation whose final product is a car. Therefore the seating system is a set of parts that goes into the customer's final product.

**2.2.2 Customer Requirement** - The customer requirement is presented in a production strategy detailing future demand, from which a Production Schedule (PS) is produced. The PS captures the actual requirement with specified lead-time from the customer in order to generate customer part and match these with the Tier 1 supplier's product part numbers. The customer order is also sent through electronic data interchange to the Tier 1 supplier's procurement system. This helps to generate the product part numbers which are used to order components from suppliers. The part numbers are linked to the customer numbers which are fixed, then migrated to the procurement

system. The components ordered from Tier 2 and 3 suppliers are delivered to Tier 1 supplier warehouse for storage prior to use.

Based on the customer order, an Individual Part Number (IPN) of 7 digits that is unique to each seat specification is sent to electronically via the manufacturing system to the procurement system, which accepts broadcast signals and specifies Customer Build requirement for material Bill Of Materials (BOM). The BOM is produced by the Engineering team in conjunction with the customer Engineering team and sent to the Materials team. The receipt of the BOM states the components required to manufacture seating systems. On average 800 broadcasts are received from the customer every day, which means a product is normally produced in 70 seconds according to the industry delivery time. The component requirement states the raw materials that are required to assemble the product for shipping and delivery to the customer. Once materials level hit re-order point, a replenishment process is triggered. Upon product delivery to the customer, the seat is fitted in the car sequentially. However, product complexity could cause constraints which might lead to delays.

The main challenge lies the fact the customer demand data is only 70% accurate on daily basis, leaving a potential for 30% of erroneous data to be used as the basis for production scheduling.

To verify the remaining 30%, human effort is required which involves manual inspection of data and amendment based on expert judgement from experience. Also, it may require clarifying with the customer. However, the process of human interference makes the data even more subject to further errors. This inaccuracy in customer data could occur due to variances in the production of the finished product (car), which necessitates some changes in the parts (seating system) to be produced by the Tier 1 supplier. Such variance in customer order poses a challenge to the Tier 1 scheduling and production because material availability is planned based on the initial customer requirement at the start of the week. It also necessitates the importance of the supplier having the right level of safety stock in order to prevent stock out to deliver customer order within the specified lead-time. Therefore the importance of this research activity which aims to identify a simple and appropriate approach to providing safety stock is highlighted. In order to achieve the aim, existing methods of inventory management in academic literature industry would be examined.

### **2.3. Inventory Management Techniques**

Several approaches to managing inventory have been developed in industry practice and academia, some of which are provided below.

#### **2.3.1 Economic Order Quantity (EOQ)**

EOQ technique attempts to find the best balance between the advantages and disadvantages of holding stock (Slack et al., 2013). The following conditions must be met in order to apply EOQ model (Chopra and Meindl, 2013, Muckstadt and Saprà, 2010; and Greasley, 2009) which are:

- Demand must be steady at a constant known rate
- All demand must be supplied from stock without any shortage
- Replenishment lead time is fixed.
- The item cost does not vary with the order size
- Annual demand exists

The equation for calculating the EOQ is presented below.

$$Q^* = \sqrt{\frac{2DS}{H}} \quad \text{Equation (i)}$$

Where D= Annual demand in units, S = Setup or ordering costs for each order, H=Holding cost per unit per year (Heizer and Render, 2014). EOQ also assumes that the entire inventory order is received at one time. However, there are times when inventory may be may be received over a period of time. This is the idea behind Production Order Quantity (POQ).

#### **2.3.2 Production Order Quantity (POQ)**

POQ model is one which is applicable under two situations

- i. When inventory continuously flows or builds up over a period of time after placing the order

ii. When units are produced and consumed or sold immediately.

Under these circumstances, consideration is made for daily production (or inventory-flow) rate and daily demand rate. Within the model, ordering cost or setup costs equal to holding costs. The model is useful when inventory continuously builds up overtime and all EOQ assumptions are valid. The equation for calculating the POQ is presented below.

$$Q_p^* = \sqrt{\frac{2DS}{H[1-(d/p)]}} \quad \text{Equation (ii)}$$

Where D= Annual demand, S = Setup or ordering costs for each order, H=Holding cost per unit per year, p=Daily production rate, or usage rate and d=Daily demand rate or usage rate (Heizer and Render, 2014). Another technique which is similar to EOQ is Economic Batch Quantity (EBQ). EBQ is focussed on optimising a multi-stage production system in order to minimise the system cost (Biswas, 2003). Both EOQ and EBQ are aimed at determining the level of inventory to order.

### 2.3.3 Re-Order Point (ROP)

Simple inventory models assume that a firm would place an order when inventory level reaches zero and the order would be received immediately. However, this is not always the case in practice due to lead-time between order placement and order delivery. The decision on when to order is expressed in terms of ROP which is presented below.

$$\text{ROP} = \text{Demand per day} * \text{Lead time for delivery (days)} \quad \text{Equation (iii)}$$

In this model, stock level is used to make provision to cover for delay in delivery lead time and the risk of stock-out (Greasley, 2009). ROP takes account of the variability of supply and demand and introduced the idea of safety stock in order to overcome some challenges which may be posed by the supplier lead-time. While ROP includes safety stock in its calculation, it is not a technique for calculating the amount of safety stock, in itself. Additionally, other approaches such as single-period model and fixed-period system are also employed to improve the inventory management process (Heizer and Render, 2014). In order to reduce or eliminate the risk of stock-out, safety stocks are provided, usually.

### 2.3.4 Safety Stock/ Safety Inventory

Safety stock or safety inventory provides extra level of inventory above the usual requirement in order to meet demand. It is carried when demand is uncertain and product shortage may result if actual demand exceeds the forecast demand (Chopra and Meindl, 2013). To calculate the safety stock level, a number of factors should be taken into account such as:

- Cost due to stock-out
- Cost of holding safety stock
- Variability in demand
- Variability in delivery lead-time
- Service level (Greasley, 2009).

In providing safety stock, the materials planner must assess the impact of a stock-out on the plant's operations, given the agreed service level, because this could affect the reputation of the firm and ability to meet customer requirement. Also, it is needful to understand the cost of holding safety stock while taking account of variability in demand and delivery lead-time in order to achieve efficiency and effectiveness. In consumer markets, temporary stock-out may only mean that a few units of sale is lost without major impact on overall profitability due to a large volume of sales units. However, with business customers, stock-out could have a major impact on company profitability, reputation as well as survival. For example, within manufacturing industries where manufacturers specialise in making high-value components or products specifically for other manufacturing or assembly plants; the survival of the supplier firm depends on their ability to meet customer requirement, hence agreed service level is very important, leaving no allowance for stock-out.

Given the significance of stock availability, different techniques and approaches have been developed in industry practice and academia to determine safety stocks. Van Kampen et al. (2010), investigated the effect of safety stock and safety lead-time on delivery performance in a multi-product setting. The methodology involved running extensive simulation experiments and the results showed that utilising safety lead time leads to higher delivery performance in case of supply variability. Sitompul et al., (2008) also explored the problem of safety stock provision in supply chain with limited capacity. They focussed on the storage capacity of the supply chain and made this an important factor for consideration. Similar to Van Kampen et al. (2010), they also employed a simulation approach to develop a model for a three-stage serial supply chain. They found that a corrective factor must be included in order to determine safety stock in capacitated system. These pieces of research did not provide a simple, transferable technique or approach to determine the level of safety stock which is generic.

### **2.3.5 Validity of Models**

While the inventory management techniques mentioned above are some of the most common ones being applied, they are not without drawbacks, hence the motivation for a research activity as this. Some of the criticisms are provided below.

- The assumptions of EOQ are simplistic
- The real cost of stock in operations are not assumed in EOQ
- The assumption of steady demand is untrue for a wide range of the operation's inventory problems so it may not be always applicable.
- The models are descriptive and should not be used as prescriptive devices
- The calculation of the EBQ does not conform to the JIT aim of minimising machine set-up times in order to increase flexibility.

EOQ, EBQ and POQ are models used to determine the amount of inventory to be ordered or to be produced. They do not specifically state the amount of inventory to be provided as safety stock to avoid stock-out. Also these techniques are more suitable for cases when the demand for stock is not dependent on the demand for other items for example the demand for cars is not dependent on the demand for mobile phones. Clearly, the case study under review is one in which the components are dependent on the demand for car seats (from customer organisation) which is also dependent on the demand for cars (from individual customers). Additionally, the assumption of EOQ which is also valid for POQ, requires demand to be steady at a constant known rate. In this case study, demand is fairly steady, but the rate is not constant as customer demand is dynamic. Additionally, the case study doesn't meet the first and fifth condition because demand is dynamic.

## **3. Research Methodology**

Saunders et al., 2009, presented the research methodology in form of an onion with different layers and the most relevant sections of these layers have been adopted in this research which are explained below.

**3.1 Philosophy** - The research philosophy underpins the research strategy. In order to achieve the aim of this research activity, interpretivism philosophy is adopted which means there is much focus on the details of the case or situation under review and the reality behind the details. The case study focuses on the assembly process within an automotive plant, a crucial element of which is inventory management which relies upon customer demand data in order to plan production. It involves the interpretation and processing the demand data from the customer in order to generate a BOM which states the components required to produce the seating systems as explained in section 2.2. The process is operated with a fixed lead time which means that there is an expected level of output.

**3.2 Approach** - Within the interpretivism philosophy, a deductive approach is adopted as it aims to identify the most suitable approach for safety stock provision, by considering existing approaches and investigating the variables involved as well as the process in order to determine their applicability to

the case under review. It would involve the collection of quantitative data and operationalisation of relevant concepts (Saunders et al., 2009).

**3.3 Strategy** - A case study research strategy would be adopted in the research activity. As defined by Yin, 2014, a case study is an 'empirical inquiry that investigates a contemporary phenomenon (the case) in depth and within its real-world context, especially when the boundaries between phenomenon and context may not be clearly evident' (Yin, 2014). This study would employ empirical data from the Tier 1 automotive and a case study would be investigated which would be based on three different products in section 5.

**3.4. Data collection method** - Data collection in case study research requires the researcher to integrate real-world events with the needs of the data collection plan, since the researcher has little control over the data environment (Yin, 2014). In order to collect data for this study, semi-structured interviews would be organised with four employees. The first stage of data collection would be familiarisation interviews to fully understand the context of the supplier's operation. To carry out the interviews, a list of themes and questions were designed around the areas of focus to guide the interview sessions. Then the next set of interviews would help to identify the challenges surrounding materials planning process. After these, analysis of the data collected would be carried out and safety stock provision would be further investigated. One case study would be identified in order to assess the suitability of the approaches in order to identify the best approach which would be validated by introducing two more products.

#### **4. Safety Stock Techniques**

The safety stock provision approaches identified from further review of literature are presented below.

- (1) King (2011) explored the idea of safety stock management and presented three approaches based on variability in demand, variability in lead time and cycle service and fill rate. The most relevant approach for the purpose of this study was the one related to variability in demand as the study focusses on overcoming the inaccuracy in demand data which is obtained from the customer. The following equation is provided.

$$Safety\ stock = Z * \sqrt{\frac{PC}{T_1}} * \sigma_D \quad \text{Equation (iv)}$$

Where Z= Z-score (a statistical figure based on the cycle service level)

PC = performance cycle or total lead time (including transport time)

T<sub>1</sub> = time increment used for calculating standard deviation of demand

σ<sub>D</sub> = standard deviation of demand

This approach is comprehensive as it takes account of lead time in a comprehensive manner. It includes the lead for manufacturing in addition to any additional time taken, before the raw materials are actually delivered to the supplier's plant.

- (2) Heizer and Render (2013), explored a variety of inventory management approaches, but only a single approach for providing safety stock was given which is presented below.

$$Safety\ stock = Z\sigma_{dLT} \quad \text{Equation (v)}$$

where Z= number of standard normal deviations (Z-score); σ<sub>dLT</sub> = standard deviation of demand during the lead time. This approach is much simpler, but it does not take account of time by including it as variable in the equation.

- (3) Greasley (2013), also explored different inventory management techniques, but the safety stock approach deduced is presented below.

$$Safety\ stock = Z * \sqrt{LT} * \sigma_d \quad \text{Equation (vi)}$$

Where Z= number of standard deviations from the mean (Z-score); LT = lead time; σ<sub>D</sub> = standard deviation of demand rate. This approach is also comprehensive as it takes account of lead time as a variable within the equation, but not as comprehensive as the one provided by King (2011).

- (4) Chopra and Meindl (2013), also explored some inventory management approaches, and provided an approach for providing safety stock to be calculated using Microsoft Excel, which is presented below.

$$\text{Safety stock} = \text{NORMINV}(\text{CSL}, D_L, \sigma_L) - D_L \quad \text{Equation (vii)}$$

Where CSL = Desired cycle service level; LT = lead time;  $D_L$  = mean demand during lead time;

$\sigma_L$  = standard deviation of demand during lead time

This approach is similar to the one provided by Heizer and Render (2013), in that it does not include lead time as a variable in the safety stock calculation. After a close investigation of the four approaches presented above, the best approach identified was the one developed by King (2011). This is because the lead time for part delivery is a very important factor in determining the availability of raw materials or components. The Tier 1 supplier has Tier 2 and Tier 3 suppliers in the UK, various parts of Europe, as well as East Asia. This means that the lead-time for each of these suppliers would vary and it is important to take this into account in material planning. Again the total lead time should take account of the manufacturing lead time as well as the transport time.

### 5. Case study application

The exploratory study employed a case study which focussed on three products.

5.1 *Product A* - The demand profile of the first product is presented below in Table (1).

Week					
	M	T	W	T	F
Quantity	160	157	69	63	144

Table 1: Product A demand data

The company has a desired cycle level of 100%, but statistically, the highest level of cycle service attainable is 99.9. The supplier manufacturing time is 3 days with 2 additional days for transportation. In order to apply equation (iv) provided in Section 4, the Z-score is derived from the cycle level and the relationship is presented in Table (2) below.

Desired cycle service level	Z-score
95	1.65
97	1.88
98	2.05
99	2.33
99.9	3.09

Table 2: Relationship between Z-score and desired cycle level

The following variables are required have been described earlier in this section. Therefore, inserting the variables into equation (iv) with a Z-score of 3.09, generates a result of 172.83 which means approximately 173 units for the week, based on the data provided in Table (1). This means the supplier would provide a safety stock of 173 units in addition to the total demand for the week. Based on the current system of safety stock provision which is simply based on experience, the supplier keeps 192 units as safety stock. This means an additional number of 19 units are currently being held at a cost of £23.29.

5.2 *Product B* - The demand profile of the second product is presented below in Table (3).

Week					
	M	T	W	T	F
Quantity	8	12	6	0	2

Table 3: Product B demand data

The total lead time is 5 days while the manufacturing lead time is 3 days. Employing equation (iv) and Z-score from Table (2) above generates a result of 17.03, approximately 17 units. Based on the current system of safety stock provision 24 units are held as safety stock, meaning an additional 7 units are held at a cost of £41.86.

5.3 *Product C* - The demand profile of the third product is presented below in Table (4). The supplier manufacturing time in this case is 2 days with 4 additional days for transportation.

Week					
	M	T	W	T	F
Quantity	364	300	244	253	286

Table 4: Product C demand data

Employing equation (iv) and Z score above generates a result of 263.29, approximately 263 units. Based on the current system of safety stock provision 600 units are held as safety stock, meaning an additional 337 units are held at a cost of £10.92.

## 6. Discussion and Conclusion

This research activity focussed on identifying a robust approach to safety stock provision for an automotive supplier of luxury cars. An evaluation of these approaches helped to identify the most suitable technique which was validated applied a case study involving three products. The results are discussed below. As shown in section 5, the safety stock provision approach developed by King (2011) was employed to determine the safety stock provision for three products.

- (i) *Product A* - Product A is a 40% trim cover for the back seats of the car which is crucial to passenger comfort. The product is normally procured from a supplier based in Europe and it is delivered daily in box quantity of 24 units. The technique proposed by King (2011) generated a result of approximately 173 units of safety stock for the week at a cost of £23.29 leading to total cost of £4029.17. When compared to the current systems of safety stock provision (192 units, costing £4471.68), a saving of £442.51 would be realised by the Tier 1 supplier. Product A is delivered in box quantity of 24 units and an order of 173 units requires 7.21 boxes which is approximately 8 boxes if the box quantity cannot be split or reduced. This shows the need for a technique to optimise safety stock and achieve cost reduction on units being delivered.
- (ii) *Product B* - Product B is a 60% trim cover for the back seats of the car which is similar to product A, but a little bit bigger. Product B also comes from the same supplier of product A, in Europe and it has the same delivery quantity and time as product A. Applying the same technique generated a result of approximately 17 units at a cost of £41.86 leading to total cost of £711.62. When compared to the current safety stock provision (24 units, costing £1004.64), a cost saving of £293.02 would be achieved. Product B is also delivered in box quantity of 24 units, therefore the previous approach to safety stock provision would require the whole 24 units to be paid for, while the new approach requires 17 units leaving with an excess of 7 units.
- (iii) *Product C* - Product C is a component which is designed to ensure that in the case of any severe impact, additional protection is provided for the passenger by eliminating excess slack from the seat belt. It is procured from a supplier in Europe which is the reason why the transportation lead-time is 6 days. Applying the same technique generated approximately 263 units at a cost of £10.92, leading to total cost of £2871.96. When compared to the current system of safety stock provision (600 units, costing £6552), a cost saving of £3680.04 would now be achieved. This amount is significant as it shows a 56% cost reduction in comparison with the current system of safety stock provision. A summary of the potential cost saving is provided in Table (5).

Description	Current Cost	New Cost	Potential Cost saving	Percentage Cost Saving
Product A	£4471.68	£4029.17	<b>£442.51</b>	<b>9.90%</b>
Product B	£1004.64	£711.62	<b>£293.02</b>	<b>29.17%</b>
Product C	£6552	£2871.96	<b>£3680.04</b>	<b>56.17%</b>

Table 5: Summary of Cost impact

The new approach to safety stock technique would help to achieve approximately 10% cost saving for product A, 29% saving for product B and 56% saving for Product C. This demonstrates the importance of a robust and methodological approach to safety stock provision in order for the Tier 1 supply to minimise costs and increase profit.

However, in order to realise these potential benefits there is need for negotiation with Tiers 2 or 3 suppliers. One option is to explore the possibility of producing smaller box quantities in order to reduce cost. Another option could be to negotiate the terms of the payment structure i.e. Tier 1 supplier would only pay for the number of units ordered rather than paying for total number of units in the boxes. The Tier 1 supplier would have to see which option is feasible in order to fully realise cost saving on the products. There is also a need for the Tier 1 supplier to constantly review and update the safety stock calculation as it would vary from one week to another based on demand data. A close analysis of safety stock provision over time (months) could help to identify trends or generate some ideas of improving the safety stock process further.

### **Limitation and implication for future research**

The technique though robust, is still dependent on good historical or demand data in order to generate a realistic safety stock quantity. If there is sharp variation in demand data, this can affect the accuracy of the result generated. There is no perfect solution to the challenge of safety stock provision because any approach adopted would always be dependent upon good demand data in order to give the right indication for safety stock provision. Future research could focus on applying the technique to a wider range of products from different suppliers in order to see if there are any trends or commonalities. Additionally future research activity could investigate the applicability of the approach to other types of manufacturing or assembly processes.

### **References**

- Biswas, P. (2003), *Optimal batch quantity models for a lean production system with rework and scrap*, MSc Thesis submitted to Louisiana State University, availability at: [http://etd.lsu.edu/docs/available/etd-0108103-140103/unrestricted/Biswas\\_thesis.pdf](http://etd.lsu.edu/docs/available/etd-0108103-140103/unrestricted/Biswas_thesis.pdf), viewed on 16<sup>th</sup> April, 2014.
- Chopra, S. & Meindl, P. (2013), *Supply chain management, Strategy, Planning and Operation*, 5<sup>th</sup> ed., Pearson, England, UK.
- Christopher, M. (2011), *Logistics & Supply Chain Management*, 4<sup>th</sup> ed., FT Prentice Hall, UK.
- Fine, C. et al. (1996), *Meeting the challenge: U.S. industry faces the 21st century*, – the U.S. Automobile Manufacturing Industry, Office of National Policy.
- King, P.L. (2011), *Crack the Code*, APICS magazine, July/August 2011.
- Greasley, A. (2009). *Operations Management*, 2<sup>nd</sup> ed. Wiley, England
- Greasley, A. (2013). *Operations Management*, 3<sup>rd</sup> ed. Wiley, England
- Heizer, J. and Render, B. (2014), *Operations Management: sustainability and supply chain management*, 11<sup>th</sup> ed. Pearson, England.
- Limere V. et al., (2012), 'Optimising part feeding in the automotive assembly industry: deciding between kitting and line stocking', *International Journal of Production Research*, Vol.15, No. 15, pp.4046-4060
- Muckstadt, J.A. & Sapro, A. (2010), *Principles of inventory management*, Springer, available at: [http://www.springer.com/cda/content/document/cda\\_downloaddocument/9780387244921-c1.pdf?SGWID=0-0-45-830013-p52114613](http://www.springer.com/cda/content/document/cda_downloaddocument/9780387244921-c1.pdf?SGWID=0-0-45-830013-p52114613), viewed on 28<sup>th</sup> Mar, 2014.
- Sitompul, C. Aghezzaf, E., Dullaert, W. & Van Landeghem, H. (2008), 'Safety stock placement problem in capacitated supply chains', *International Journal of Production Research*, Vol. 46, Iss.17, pp.4709-4727.
- Saunders, M., Lewis, P. and Thornhill, A. (2009), *Research Methods for Business Students*, 4<sup>th</sup> ed. Pearson, UK.
- Slack, N., Brandon-Jones, A. and Johnston, R. (2013), *Operations Management*, 7<sup>th</sup> ed. Pearson, Harlow, UK.
- Van Kampen, T.J., Van Donk, D.P. & Van der Zee, D. (2010), 'Safety stock or safety lead time: coping with unreliability in demand and supply', *International Journal of Production Research*, Vol. 48, No.24, pp.7463-7481.
- Yin, R.K. (2014), *Case Study Research*, 4<sup>th</sup> ed., Thousand Oaks, Sage, UK.