Development of an Inventory Management Program for Warehouse Storage of Raw Materials in a Continuous Chemical Manufacturing System to Prevent Production Deficiencies

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Abstract

Raw materials are the key to every manufacturing process, without raw materials or with inadequate quantities the entire production system could be in jeopardy. This is true for continuous manufacturing processes because the entire production system may be in a chemical manufacturing facility the packaging materials are equally if not of more importance than the raw material inputs since without adequate packaging materials to package the finished product there is no need for process inputs. The goal of manufacturers is to produce a maximum quantity of finished goods while ensuring customer satisfaction, which in turn maximizes profits. An efficient inventory management program is critical to maximizing production capabilities of a continuous production process, while minimizing production deficiencies. The objective of this study is to ensure proper levels of onsite supplies and/or materials while eliminating the issues that arise with the overstocking and/or under-stocking of these required inventoried items. Although there are several aspects that contribute to the controlling of onsite inventory throughout the production processes, the uncertainties affiliated with the supply chain, unprecedented inventory costs, and fundamentals of inventory are the greatest variables that effect any inventory management system. These components are analyzed and optimized to create an adequate program for inventory management within the manufacturing environment.

Keywords
Raw Materials, Inventory Management, Manufacturing, Packaging, Engineering Management.

1. Introduction
Chemical manufacturing facilities are faced with constant production demand from customers and stakeholders. Often, the production demand becomes the focus of all personnel within the organization, however the focus must swing back to the initiation of the processes which involves the system inputs. Without proper levels of management pertaining to the material inputs there will be no production (Suwandi et al. 2018). The raw materials of any manufacturing facility are more important to the day-to-day operations then the production capacity regardless of the production demand. For every ounce of finished product that is produced by a manufacturing facility, there are likely a few if not hundreds of raw materials which must be sourced and inventoried for that process. With the increase in the individual raw materials that are used in any manufacturing process, each one is a potential source of non-conformance which could eventually impact the final product and thus the production demand (Rajeev 2008). The packaging department of any manufacturing facility is often undervalued due to its critical aspect pertaining to the production process. Proper inventory management is required for packaging materials since it directly affects the management of finished goods.

A continuous production chemical plant which has been in operation for more than fifty years will be used as the model to develop an effective inventory management program for raw packaging materials. This plant began operation

over fifty years ago as a small batch production facility, as the production demand continued to increase each year, the necessary capacity increase required a continuous operation to meet the product demand. This plant produces a single solid finished product in two different grades (specifications). Due to the nature of the chemical produced some packaging capabilities are limited to prevent product decomposition. Since this chemical is specifically sensitive to excessive moisture and heat, all package types used are designed specifically to reduce exposure to these elements. Additionally, the product is limited to a max storage quantity of one metric ton. There are three main packaging types used by this facility, supersacks, poly lined paper bags, and a combination package consisting of unlined paper bags in a lined fiberboard box. The supersack is a flexible intermediate bulk container (FIBC) which contains one metric ton of finished product. For each supersack produced at least eight individual components are needed to complete the package in preparation for shipping and typically each order contains nineteen individual supersacks.

The poly-lined paper bags are a combination package in which forty-two individual poly lined paper bags are filled with twenty-five kilograms of finished product, heat sealed, and stacked on a pallet. In addition to the forty-two bags at least six additional components are needed to complete each pallet for shipping. Each of these bags are preprinted with the appropriate GHS hazard identification information, however there are several versions of the same bag since the GHS information varies depending on the country to which the material is shipped. The third package type which only accounts for about three percent of total production orders, is a combination package that consists of preprinted unlined paper bags which are filled to either five or twelve kilograms, sealed and layered into a fiberboard box containing a watertight liner. Despite producing only one finished product, the site must maintain inventory of over seventy different packaging items, and if just one of these items runs out unexpectedly, the entire production system will not perform efficiently.

Maintaining inventory is a major balancing act for a manufacturing company, since the complexity only increases as the number of materials that must be inventoried increases. Therefore, a systemic approach should be employed to handle the complex system operations (Nagahi et al. 2019). Inventory must be maintained for all types of production systems, however maintaining sufficient inventories for continuous productions systems is slightly more complex than in a batch production system (Kamilah 2018). Just as it sounds a continuous production system has a continuous supply of raw materials going into the manufacturing process and a continuous supply of finished product being produced. As the product is produced it is packaged into a variety of package types of various capacities. Managing inventories of these packaging materials in a continuous production system has an increased level of complexity, since the amount of material throughput often fluctuates so that an increased or decreased amount of raw material may be consumed from month to month, making planning and forecasting extremely difficult. Inconsistent production rates make inventory planning challenging and increases the possibility of having an over stock issue or a stock shortage problem, both of which are linked to the costs associated with the excess stored or increased rush for raw materials (Comeaux, 2006). The goals of this project include the management of onsite reserves, inventory accountability, and the safeguarding of the organization's clientele.

2. Literature Review

Inventory management seems like a straightforward concept that everyone must deal with at some point in life. Whether related to groceries, medications, or toilet paper, there is a process that is used to ensure that these items are always available and are restocked before issues occur. It is an understood philosophy but, to run out of food, medications or toilet paper could have serious effects on the normal operation of a household. Although it is a simple concept to understand, the implementation of inventory management programs in industrial chemical production facilities is like this concept but becomes much more complex as the number and hazardousness of these items increases. This is true of all production facilities, but the catastrophic effects of improper inventories typically mean a halt to the entire production process and massive profit losses (Suwandi et al. 2018). Despite being an extremely important part of the production process, inventory management programs are not often given the time and effort they require to be made effective and are left to be managed on an elementary basis (Rajeev 2008). It is critical to understand the basic principles of inventory management before developing a new process for managing inventories. The management of the inventory of the raw packaging materials for this continuous chemical production facility must take into consideration the seventy different pieces of packaging materials, where each item should have an inventory management process that takes into consideration the current inventory, the order quantity, the turnover time to produce the item, the transit time to arrive, and the scheduled production for the following month (Rawat 2015). Since none of these variables are constant, the inventory is ever evolving and can change at any moment, which creates an unstable and unpredictable system.

The current system used at this site utilizes a spreadsheet, which includes the current quantity, the order quantity, and the minimum inventory reorder point. On a monthly basis, an employee must physically take inventory of each of these items to determine the exact inventory and to decide if the on-hand stock is above or below the reorder point. Packaging materials must be effectively managed, since it directly effects the finished products that can be made and orders that can be fulfilled (Rawat 2015). The problem with this type of manual inventory management process is that the actual on hand inventory is only truly known at the exact moment that it is counted, however that quantity is subject to human error. This type of management could lead to potential stockouts of key items before the end of the month when inventory is recounted (Bowersox, et al. 2020). Also, there is a potential for overstock of some items to occur, since the different package types have highly variable demand each month (Comeaux 2006). The two primary package types used by this site includes flexible intermediate bulk containers (FIBCs) in the form of supersacks and lined multi-wallpaper bags which are both UN certified packages that must be recertified on a regular basis.

A different supplier is used to provide each of these package types; however, both are custom made and printed specifically for the product made at this site and are not stock items from the suppliers. These custom package types are required for the chemicals being packaged; however, this leads to increased lead times as compared to other packaging items that may be standard stock items, and further complicates the inventory process. Although packaging materials do not have traditional expiration dates, these package types do have a timeframe in which they must be used to ensure they are of the same strength as they were when they were UN evaluated and certified. Additionally, the artwork that is printed on the packages contains regulatory information that is subject to change with associated regulations, maintaining excessive inventories of these package types is unreasonable, and may lead to excessive and unnecessary disposal costs. Due to these requirements and inconsistent lead times of these packages, maintaining consistent inventories of these materials is unpredictable which leads to higher average inventories to be maintained by the site to ensure there is always an available safety stock.

3. Methods

Managing inventory is critical from a production demand standpoint but it also creates an opportunity for increasing overall organizational profitability (Atnafu 2018). Cashflow is critical to all businesses especially continuous chemical manufacturing companies since higher front-end investments are often seen in chemical manufacturing systems, specifically for raw material inventories. Despite being one of the most important financial assets of any company, inventory management is often forgotten about and is not always optimized for cost savings (Norazira et al. 2018). There are various costs associated with inventory management, but cost reduction may be achieved by evaluating ordering costs, holding costs, and stock-out costs (Kamilah 2018). The act of achieving cost savings via inventory management practices requires a strategic balance between overstocking and stock-outs to maintain the exact inventory needed to optimize the system (Kamilah 2018). A stock-out situation, specifically of packing materials, often leads to reduced production rates resulting in lost sales, while over-stock of packaging inventory leads to increased investment and holding costs that are completely unnecessary (Almaktoom 2017). Although it seems obvious to simply change the inventory management process as described in Figure 1 can assist in cost savings, is a much larger and more complex problem that must consider the entire production system.

The inventories maintained by a manufacturer represents a substantial portion of that company's working capital, which is not only affected by the quantity inventoried but also by the amount of time the inventory remains in stock (Rajeev 2008). Any inaccuracies in the inventory can create significant issues for the company, such as production loss, production of non-conforming materials or production of work in progress materials (Rajeev 2008). The cost savings created by effective inventory management practices will optimize all related inventory costs, which then leads to higher rates of return and increased overall company performance (Norazira, et al. 2018). In the case of packaging materials, the cost savings must be done in accordance with the production system to avoid jeopardizing order fulfillment for end customers and maintaining customer satisfaction (Michel 2016).

Maintaining higher quantity inventories of all packaging materials is required for high volume production processes such as in continuous production (Oláh et al. 2017). Increasing storage capacity could increase inventories of raw materials and would allow additional safety stocks to be maintained to prevent stockouts. However, increasing storage capacity would not only increase the amount of on hand available inventory, but also increase the costs of the additional inventory as well as the additional cost of warehousing (Kruger 2005). The cost associated with inventory include the capital costs of the physical inventory as well as the warehousing and storage costs, the disposal costs must also be considered if the inventory must be disposed of before use (Lee 1992). Greater than half of the total product cost can be attributed to the costs of obtaining and maintaining raw material inventories (Norazira et al. 2018).

Optimization of the raw packaging material inventories is critical; however, this must be achieved in direct conjunction with the production planning process to ensure the entire system is fully optimized to minimize the inventory to sales ratio and achieve higher profit margins and increase overall profitability and competitiveness (Norazira et al. 2018). The plant, although small in square footage, produces enormous quantities of finished product and has an unachievable production demand. Inventory of raw packaging materials is not often looked at as a vital component, but more of an unavoidable feat that must be dealt with to ensure production is never limited by the raw material inventories (Atnafu 2018).

Although not limited by the costs invested into packaging material inventories, the plant could potentially find additional funds by optimizing this process. Smaller quantities must be ordered on a more frequent basis to help reduce the holding costs associated with maintaining larger inventories, however this leads to an increase in the ordering costs (Norazira, et al. 2018). The best way to minimize the ordering costs would be to increase the quantities ordered and decrease the total number of orders placed (Norazira, et al. 2018). Assigning value to stockout costs is not always straightforward, however this is avoidable, with proper inventory management but, they may still occur if all packaging items are not properly inventoried. This may lead to an unfilled order, which may lead to customer dissatisfaction or even a complete loss of customers and future sales. Shelf life, although normally associated with food or unstable chemical products, also applies to some packaging materials as well. Disposal costs must also be considered in the storage of raw packaging material inventories, for example, if a version of the preprinted packages is not completely used before the regulations change and the artwork is updated, then the older non-compliant versions may have to be disposed of before they can be used. In doing so, not only is the cost of the item lost but also all associated ordering, holding, and disposal costs, meaning it costs more to throw out unused inventory than not to order it in the first place.

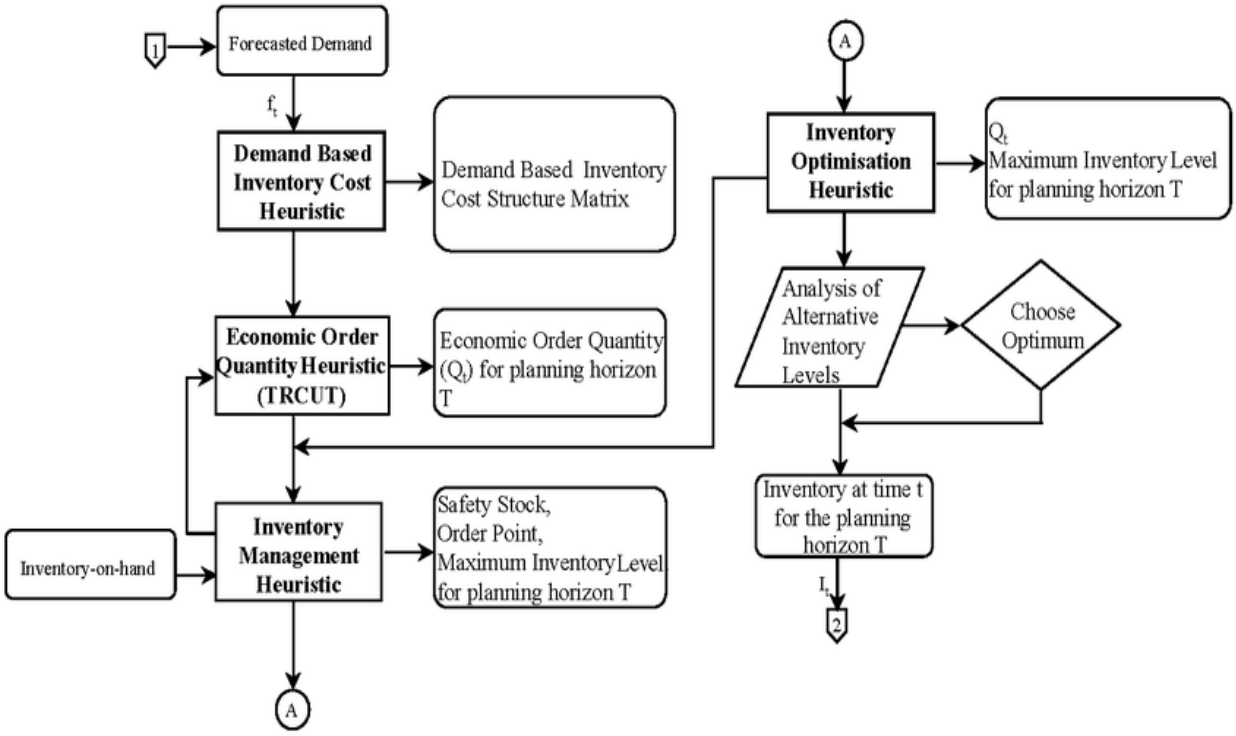

Figure 1. Forecasting and inventory management flow chart (**Almaktoom, 2017)**

4. Data Collection

Effectively managed inventory processes allow for flexibility between supply and demand as they fluctuate (Williams 2008). Flexibility and responsiveness are key to optimizing unpredictable supply chains, while efficiency is key to optimizing more consistent supply chains (Matani 2010). The risks associated with inventory management can be significant, however this risk is variable depending on where they fall within the supply chain (Bowersox et al. 2020). A major factor to managing a successful supply chain is the assumptions of demand uncertainty used to reduce risks.

In a consistent non-variable system, there is extraordinarily little uncertainty in the production demand and the inventory management program can be defined linearly. However, when the demand is highly variable, the uncertainty cannot always be planned for, leading to the necessity of a flexible system that can respond quickly to unplanned variations (Matani 2010). At the plant, the production demand is highly consistent, but the packaging type demand is highly variable which creates major uncertainty for inventories and safety stocks of packaging materials. Additionally, the mechanical integrity of the production facility can change the packaging type filled at any moment.

The plant, like most production facilities, has many pieces of equipment that are well aged and more susceptible to increased maintenance needs. If the bag packaging system goes down due to unplanned maintenance needs, the material must then be packaged in supersacks until the bag packaging system is again functioning as intended, thus day to day production packaging demand is highly uncertain. Although inventory planning can be maintained using numerous calculations and "fudge factors" to help account for uncertainty, it can never be completely optimized by a single calculation. Production packaging demand is highly variable, which makes ordering and maintaining inventory of packaging materials difficult, in addition to this is the uncertainty that comes from the supplier of the packages. The plant orders custom printed packages, so there is no safety stock maintained at the supplier. When a new order is placed, depending on the package supplier's current production demand, the lead times that the plant expects to receive the ordered materials can vary from eight to ten weeks.

With the plant's variable packaging demand, the difference of two weeks to receive packaging materials can be the difference in filling a customer's order and receiving it on time or delaying the order by two weeks and the customer having to delay their production and all associated supply chain factors thereafter. Cost is often a driving factor for a manufacturing company but by optimizing inventory management, cost savings can be achieved. One key to simultaneously minimize costs and inventories in the manufacturing process can be achieved by developing and maintaining an effective supply chain (Oláh et al. 2017). There is ever increasing pressure on the global supply chain which significantly impacts all manufacturing and coordination companies worldwide.

5. Results and Discussion

This supply chain pressure must be overcome by suppliers, manufacturers, and retailers by coordinating and planning with one another to optimize the supply chain operation (Oláh et al. 2017). The collective goal of each of these units is to supply the correct item to the correct location at the correct time and, to ensure reoccurring business by providing elevated levels of customer satisfaction (Williams 2008). A successful supply chain is a complex network dependent upon strong business relationships between all the involved entities (Oláh et al. 2017). Slight variations at one end of the supply chain can have increasingly significant impacts each step up the supply chain. For example, as described in Exhibit 1, the company that supplies the glue to the bag manufacturer, who then uses the glue to produce the pre-printed poly-lined paper bags which are critical to the production of finished product from the plant, despite not being directly related to the finished product, is critical to the optimized operation of the supply chain of finished goods leaving the plant to fulfill customer orders. An effective inventory control policy is a critical part of effective order fulfillment and customer satisfaction (Yang, et al. 2019). As shown in Figure 2, A well-organized supply chain optimizes multiple components in the process, such as the transportation and warehousing or the warehousing and inventory functions (Williams, 2008). The decisions made concerning inventory management and production planning at the plant will directly impact the operability of their customer plants downstream receiving the finished product as a raw material, since any delays upstream will impact their supply chain (Lee 1992).

Figure 2. Examples of Package Types: One Ton Super Sack and Stacked Pallet of Twenty-Five-kilogram Poly-lined Paper Bags.

5.1 Numerical Results

Inventory management in a continuous chemical manufacturing facility is critical to maintain constant production which in turn helps to optimize overall performance and maximize company profitability. Although it seems odd to say that something as simple as inventory management could have a such a significant impact on an industrial chemical facility's operation, the proper management of any process is critical respective to its function. Optimizing performance and maximizing profitability as expressed in Figure 3. is not exclusive to inventory management, but in fact happens to be the same principles that are seen in engineering management programs of manufacturing facilities. Engineering management principles consider the entire manufacturing system from top to bottom. They start at the top with managing inventory of raw materials, spare parts, and even employees which ensures the facility is always operating efficiently, as well as production and organizational planning which ensures production is efficient and increases customer satisfaction. Just as minimizing investment costs as shown in Equations 1-3. is important to inventory management, the optimization and proper allocation of all costs associated with normal plant functions is a critical role in engineering management. The principles of engineering management consider the interests of the stakeholders, the physical operation of the facility, and the employees of the facility. It could be said that inventory management is the same as engineering management, only it is focused on applying these principles to the specific process of maintaining inventories.

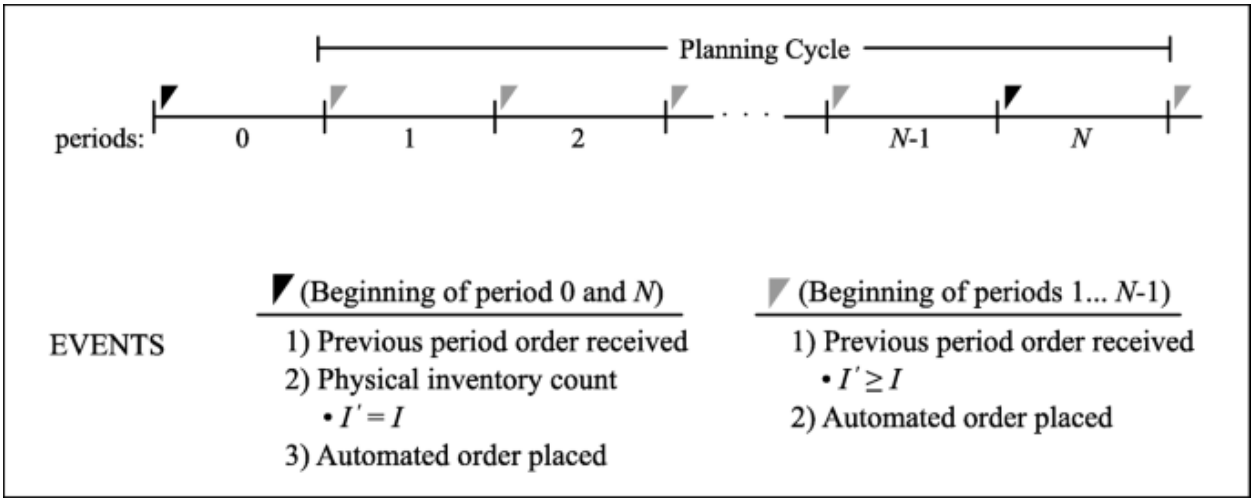

Figure 3. Point of use inventory management analysis

$$\text{Inventory Turnover} = \text{Annual Cost of Goods Sold/Average Inventory in Dollars} \quad (1)$$

$$\text{Weeks of Supply} = \text{Average Inventory on Hand in Dollars/Average Weekly Usage in Dollars} \quad (2)$$

$$\text{Days of Supply} = \text{Average Inventory on Hand in Dollars/Average Daily Usage in Dollars} \quad (3)$$

Equations 1-3. Inventory Management Numerical Calculations

5.2 Results

These fluctuations in the supply chain which is illustrated in Figure 3 below with the example of the glue manufacturer, is often referred to as the bullwhip effect and may be reduced by good inventory management programs. Even the slightest upset at any point in the supply chain can lead to significant upsets in other parts of the supply chain (Donovan, 2003). Although this phenomenon is often seen as an unavoidable impact of all supply chain processes, the reduction of this bullwhip effect, as much as possible, can help to reduce the severity of the impact downstream (Donovan, 2003).

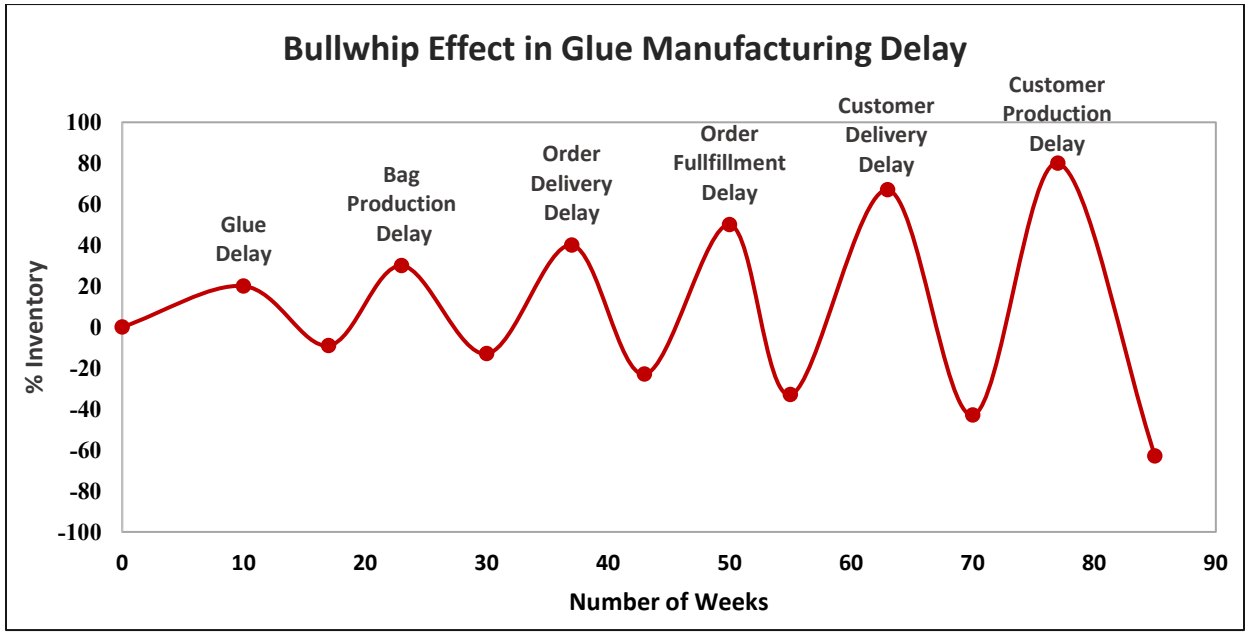

Figure 4. Graphical Representation of Bullwhip Effect as Described for Glue Manufacturing Delay in the Production of Pre-Printed Poly-Lined Paper Bags.

5.4 Validation

When managing a chemical manufacturing facility, specific attention must always be given to assure all aspects of the plant are properly maintained and ensure continued operation to meet production demand. The management of raw material inventories is one of the most critical components of a plant that must be maintained to ensure high-capacity operation. Proper implementation of an effective inventory management program ensures increased company performance and profitability just as engineering management does for the entire operation of the plant. There is no single easy solution to correcting inventory mismanagement, the solution to proper inventory management must be multi-faceted. Some of the factors that must be considered when dealing with inventory management include production demand, physical capacity, supply chain lead times, and all associated costs of purchasing, holding, and

using raw materials (Rawat 2015). The basic key factors to improving inventory management include a positive management attitude, adequate training for employees, and effective communication with vendors (Norazira et al. 2018). The site currently employs SAP as an enterprise resource planning (ERP) system to manage the production and inventory of raw materials and finished goods. Although this system has been quite effective in the raw chemical and finished product inventories, the management of packaging materials has not been as effectively managed through this system, and the availability of the functionality alone is not enough to make an effective system (Rawat 2015). Ideally a system such as SAP would maintain an exact inventory, however SAP is only as effective as it is allowed to be, if inventory is used or disposed of and SAP is not updated with the change in inventory, the information in SAP will not be correct. To address this, the site must define a process to ensure all inventory is always accounted for in a way that is easily managed by all site employees. Ideally an inventory management system, such as SAP, would be used and inventory would theoretically be properly accounted for and planned for which would take all factors into account to essentially "know" when to reorder. However, there is often a gap between the inventory management system and the production planning system and when these systems are not seamlessly integrated, there is an increase in opportunities for errors and inaccuracies in the data (Lee 1992). Because of the increased potential for errors, it is often unreasonable to forecast production for more than a month at a time to prevent over or under stocking packaging material inventories (Lee 1992).

Costs affect every aspect of a manufacturing company and is often the value by which success is measured, it is always ideal to optimize cost efficiency in any way possible. Inventory is often overlooked as a source of cost savings; however, it is often a key point in need of optimization. For a system to increase in cost effectiveness, identification of each component and how much of an impact they have on the inventory levels would be the best starting point. Often production quality problems create unplanned uncertainty in inventories, especially for packaging materials as work in process materials may be created and then reworked, which then incurs the cost of packaging twice. Additionally, forecast and production uncertainty always increase costs of raw packaging material inventories, either by increasing holding costs of inflated inventories or of costs associated with stockouts. Finally, inadequacies of supplier lead times or production times are a major driving force for inventory levels and can be very cost ineffective, as the investment costs and holding costs of inflated inventories can be quite large and offer no return on the investment.

6. Conclusion

The supply chain issues are the most difficult to overcome due to the number of players involved in the chain, upstream and downstream from the manufacturer. Additionally, supply chain is maintained on a global scale and must be addressed likewise, leading individual sites to have to adjust to allow for the variable lead times and other supply chain impacts when managing inventory. Although the site cannot directly affect the supply chain, the impacts of it can be seen directly at the site, from inconsistent lead times to delayed delivery of products to customers.

These things can be exceedingly difficult for the company since the cost of the raw materials has already been spent, however the raw materials may not be received until several months later affecting the company's cashflow. Some of the key components that contribute to the uncertainty associated with the supply chain include, lead times, delivery conditions, transit times, demand, and manufacturing production delays or rework (Lee 1992). The initial step that must be made to reduce these supply chain issues would be to identify the exact sources of variability and to track the extent to which each of these variables affect the site specifically (Lee 1992). The site currently maintains and responds to supply chain uncertainty well by adjusting inventory levels to prevent potential stockouts, to make a more effective inventory management program the site must directly address the root causes of the supply issues starting with the addressing suppliers directly (Lee 1992). Although this may be easier said than done in an industrial manufacturing facility, every step in the right direction can only help move away from the current ineffective system. An improved inventory management system, or an improvement in the integration of an existing inventory management system could provide cost savings, overcome an unreliable supply chain, and increase sustainability of the production system.

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