Modelling and Simulation of Inventory Replenishment Policies and Comparison of Target Days Vs Actual Days of Inventory Held

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***Abstract*— Supply chain managers often apply aggregate planning techniques to develop make or buy decisions or even make for stock versus make to order scenarios for example. These scenarios often contain combinations of inventory holding vs capacity installed. Many supply chain managers have used 'what-if' decisions to develop supply chain scenarios to help them determine optimum results in terms of low cost and improved customer service. This study aims to create eight scenarios of varying inventory replenishment policies for one fast moving consumer goods (FMCG) organisation. The aim is to provide the supply chain manager with alternative options for lower inventory and yet be able to service the FMCG businesses at lowest cost. The results show that this allows supply chain managers to pick the scenario that optimises an organisation's resources and competitive strategy.**

Keywords— *inventory replenishment, make for stock, make to order, modelling & simulation, order frequency, stock in days*

1. Introduction

Even-though many researchers have studied inventory models for deteriorating items that become waste or obsolete such as electronic components, food items and fashion goods, a lot depends on how a supply chain manager is able to use a modelling and simulation process to pick out the scenario that best fits an organizations ability to service the market at the lowest possible cost. Ref. [1] found that there is an impact of lean production practices on operational and financial performance of manufacturing firms. Failure to evaluate an optimized supply scenario will only result in excess inventory or capacity. Cisco had to write-off $1.2 billion worth of inventory due to holding too much of an item in finished goods. Tesco UK has admitted it had generated 30,000 tonnes of food waste in the first 6 months of 2013. The Food and Agriculture Organization of the United Nations (FAO) has indicated that about 32 percent of different types of food produced globally is lost or wasted. The approach in this study is to model and simulate inventory replenishment policies for finished goods inventory. The two questions that Supply Chain Managers ask in inventory replenishment are when to order and how much to order for any item and these two questions impact the amount of inventory and determines target days of inventory held. This study looks at modelling Make to order (MTO) and Make for stock (MFS) schedules in a manufacturing and distribution organization for the fast consumer goods industry to see the impact of target days reduction in finished goods held. Traditionally, all items in fast moving consumer goods business are made for stock and held in warehouses or supermarket shelves and common features of this made for stock environment are huge amounts of working capital tied up in a business, resulting in the high probability of slow-moving stock being held [2]. According to Ref. [3], process industries excluding pharmaceuticals, account for €2750 billion in revenues globally and inventories make up 56.7% of working capital for global industries. There is

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therefore much scope to manage slow moving items differently by applying a make to order approach when inventory reaches zero. At this point of replenishment, a manager may transfer inventory between warehouses or manufacture a small batch to be produced and replenished quickly for inventory with low order frequency. It can be deduced that since these items are probably slow-moving items in view of its low order frequency [4], customers may not notice its low product availability at zero. However, it is important to determine which items are MTO as only very slow-moving items should be considered for a quick response replenishment strategy.

2. Literature Review

The literature will begin by looking at modelling and simulation. The development of the body of knowledge for modelling and simulation (M&S) is seen as applicable to industry from perspectives when there is enough knowledge accumulated in science, technology, and craftsmanship [5]. Simulation can be used in many important application areas. A simulation is an attempt to duplicate the characteristics, appearance and features of a real-world system mathematically and study its properties and operating characteristics, so that conclusions can be drawn for action decisions based on the results of the simulation [6]. In engineering products and systems, simulations of products, materials, and production processes will be used more extensively in plant operations. These simulations will leverage real-time data to reflect the physical world in a virtual model, which can include machines, products, inventory, capacity, supplies and humans.

2.2 General use of simulations

Ref. [7] defines a simulation as an attempt to duplicate the characteristics, appearance and features of a real-world system mathematically, create a scenario and study its properties and operating characteristics so that conclusions can be drawn for action decisions based on the results of the simulation. Simulation scenarios can be made for several areas (Table 1.0)

Table 1. Simulation applications.

Simulation Applications	
Ambulance location and dispatching	Bus scheduling
Assembly-line balancing	Design of library operations
Parking lot and harbour design	Taxi, truck and railroad dispatching
Distribution system design	Production facility scheduling
Scheduling aircraft	Plant layout
Labour-hiring decisions	Capital investments
Personnel scheduling	Production scheduling
Traffic-light timing	Sales forecasting
Voting pattern prediction	Inventory planning and control

2.3 Use of simulation in manufacturing

According to Ref. [8], manufacturing systems provide one of the most important applications for simulation and simulation has been used as an aid in the design of new production facilities. Ref. [8] highlighted that models of manufacturing systems must consider several aspects and take into account a number of characteristics (Table 2.0).

Table 2. Characteristics of Simulation Models for manufacturing systems.

Characteristics of Simulation Models for manufacturing systems	
Physical Layout Shift schedules & job duties	Make to order and make for stock schedules Production control
Capacity rates and breakdowns	Supplies, receipt and storage
Maintenance, resources and tooling	Work-in-process and finished goods
Work centres	Packing and shipping
Product flow and routing	Customer orders and stock keeping units

Once the scope defines the boundaries of the simulation, supply chain managers may be able to develop scenarios that can then be simulated at many different levels of detail. This study uses forecasts of demand to develop simulations of inventory and capacity. Eight scenarios will be developed based on 'what-if' inventory parameters in relation to capacity installed. At the heart of the scenarios is the use of the order frequency variable in categorizing inventory and computing target stock in days (SID) for comparison with actual inventory held by an organization. [9].

3. Using case study data for inventory modelling

Case study methods are controversial in its approach to data collection but many researchers in social science studies have recognised the approach as acceptable [10]. According to Ref. [11], a single-case study research provides a statistical framework for making inferences from quantitative case-study data. In this study, a single-case study will provide the researcher with the whole spectrum of order and inventory records for further analysis. Ref. [12] notes that there is research value of case reports of industries or operations management in practice. From case reports, since the Industrial Age, many theories have continued to provide manufacturers with leading models and applications in the areas of inventory management, such as which items to make for stock (MFS) or made to order (MTO), when to order and how much to order systems. This study will consider simulation and modelling to derive the theoretical minimum of inventory to be held. The perfect formula for determining the right amount of inventory (also called the Science of theoretical minimums) helps Supply Chain Managers to minimize the level of inventory to optimize customer service, as both working capital targets and customer service are conflicting in nature [13]. 'What-if' finished goods simulation results to derive target SID, will be used to make comparisons with actual inventory. The data comprises 1 year of order volume data, a snapshot of inventory held and capacity data. A similar study [14] also used 1 year of sales data in attempting to analyse demand management for downstream wholesale and retail distribution and it has been researched that data from implementation of Enterprise Resource Planning (ERP) systems boosts organization performance [15]. The organization in this study is a FMCG manufacturer and distributor. The organization operates 28 warehouses and distributes the many stock keeping units (SKUs) on offer to wholesalers, retailers and even directly to supermarkets and hypermarkets. Order volume is based on annual orders received and inventory held is a snapshot of end–period inventory in the 28 warehouses that it operates from. The organization's effective manufacturing capacity operates on a 5-day week plan and uses 1 shift for most processes but for bottleneck processes such as for small batch machines, the organization operates on two shifts.

3.2 Data preparation for scenario simulation modelling

The process for data preparation and the pre-simulation routines as illustrated in the flow-chart (Figure 1.0) shows each individual aspect of the data collection and pre-simulation routines before what-if parameters on inventory categorization and replenishment policies are used to compare the output of a simulation with actual FG inventory held. Figure 1.0 shows the broad processes that will be needed for data preparation, and the pre-simulation routines as required in a demand planning software tool that is used to run the simulation.

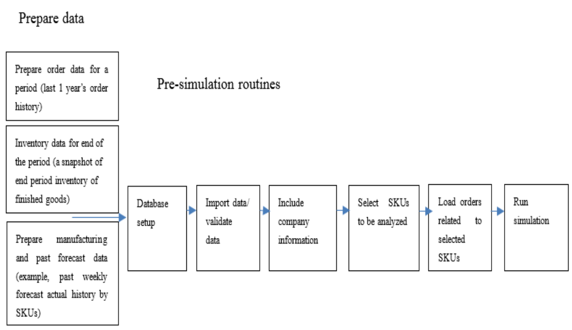

Figure 1. Flowchart of the data preparation/pre-simulation routines in this study

Once the data has been collected and imported into the demand planning tool, a Finished Goods (FG) simulation process will be designed to determine 'what-if' FG replenishment policies, with outputs (target days of FG) compared to actual days of FG inventory (Figure 2.0). Some scholars have written that such data can be used to determine expansion of productive capacity [16].

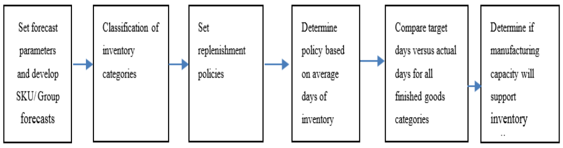

Figure 2.0. Broad features to derive 'what-if' parameters on inventory classification and replenishment policies.

3.3 Data used in the study

This research will look at a complete set of SKU data within warehouses in a country for a single-case study. The selection of a participant in this research is a single organization that manufactures and distributes fast moving consumer goods (FMCG) to the market that has a substantial number of warehouses and SKUs held as inventory (Table 3.0)

Table 3. Number of records used in the study

Description of data	Number of records
Number of warehouses	28
Number of unique stock keeping units	944
Number of warehouse/ records	7442
Number of unique order records	7,530,192

The unit of analysis are warehouse/stock keeping records, which will be categorized into inventory categories by warehouse, and different days cover policies will be set to derive 'what-if' targets of SID. In this case, information from order, inventory and capacity data will help the Supply Chain Manager combine both sales and operations views [17] to derive optimal balance in demand and supply.

3.4 Inventory parameters used to determine base scenario

The organization in particular, uses 2 weeks (14 days) of safety stocks and 2 days of lead time to set their Re-order point (ROP). To determine the target SID held, 3 scenarios are initially chosen (Table 4.0) with varying days cover policies for quantity to be ordered (Q), when the ROP is reached.

Table 4. A set of inventory parameters used to develop the base scenario for inventory simulation.

Categories	ROP		Q1	Q2	Q3
	Lead time (days)	Safety stocks (days)		(days)	
A	2	14	7	10	14
B	2	14	16	24	31
C	2	14	31	48	62
Average inventory (days)			18	19	21

- Average inventory days uses the formula: safety stock + Q/2 in days of inventory

The choice of choosing a particular policy will depend on whether the policy matches existing capacity. This chosen policy will be used for further simulation to reduce days cover policies using safety stocks linked to desired service levels and the use of the order frequency, coefficient of variation and 'no orders in last "x" days' variables to test whether such policies may yield reduced target SIDs.

3.5 Overview of the approach used in this study

8 scenarios were used to model 8 simulations. Annual order data for orders received by an organization with twenty-eight warehouses were used to determine target SID held, whereby a re-order (R) replenishment rule using arbitrarily set safety stocks of 2 weeks and a lead time of 2 days developed a base scenario. The lead time of 2 days is the average turnaround time for inventory replenishment orders of the organization. 3 different days cover policies for quantity (Q) by ABC volume-based categories were compared with existing capacity and one was chosen based on available capacity for the base scenario. Following this, seven other scenarios were developed as per Figure 3.0.

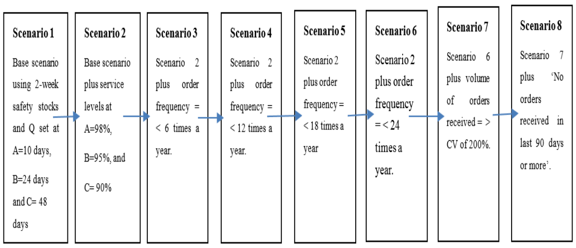

Figure 3. Progression of scenarios 2 to 8 from base scenario 1.

Scenario 2 used a user defined safety stocks as A=98%, B=95% and C=90% service level.

Scenario 3 used a user defined cut-off order frequency = < 6 times a year to determine make to order (MTO) or D items for slow moving inventory items.

Scenario 4 used a user defined cut-off order frequency = < 12 times a year.

Scenario 5 used a user defined cut-off order frequency = < 18 times a year.

Scenario 6 used a user defined cut-off order frequency = < 24 times a year.

Scenario 7 used a user defined coefficient variation (CV) of = > 200% rule to determine order size variability for demand that occurs less frequently in varying order sizes.

Scenario 8 used a user defined 'No orders last 90 days' rule to determine inventory items that were beginning to slowdown in demand.

Following this, an independent t-test was used to compare the differences between the scenarios and actual inventory held to see if significant differences do exist statistically as this will show whether inventory savings can be made.

4. Using t-tests to determine effectiveness of a chosen inventory replenishment policy

In this study, the aim was to develop scenarios of likely replenishment policies that will result in lowering of target inventory days held and compare these target days with actual days of inventory held. A t-test was used to test the effectiveness of the chosen policy, and the following hypothesis tested for various scenarios.

H_0: µActual SID ≤ µScenario SID

H_1: µActual SID > µScenario SID

Table 4 summarizes all t-test results.

Scenario	Description	Mean of Scenarios	Mean of Actual	Variance of scenarios	Variance of	T-test result	P(T<=t) one-
1	Q (A=10, B=24, C=48 days), Safety stock=2 weeks	18.85	22.4	0.31	47.93	0.0051 30239	
2	Safety stocks = Service Levels (A=98%, B=95% & C=90%)	13.35	22.4	3.40	47.93	7.2182 5E-08	
3	Scenario 2 + order frequency = < 6	13.25	22.4	3.07	47.93	6.9887 2E-08	
4	Scenario 2 + order frequency = < 12	13.22	22.4	3.07	47.93	6.4340 5E-08	
5	Scenario 2 + order frequency = < 18	13.18	22.4	2.79	47.93	5.8092 9E-08	
6	Scenario 2 + order frequency = < 24	13.15	22.4	2.55	47.93	5.1435 2E-08	
7	Scenario 6 + CV = >200%	12.93	22.4	2.37	47.93	3.2350 8E-08	
8	Scenario 7 + No orders = >90 days	11.89	22.4	2.84	47.93	4.6139 8E-09	

The **P(T<t) one-tailed** value is less than 0.05 for all scenarios. Hence, we can conclude that there are

statistically significant differences between the target SID and actual SID in this study. The desired objective of industry is to reduce uncertainty and the higher variance in the actual SID held suggests that demand is highly variable and specific treatment of low frequency items is required. The methodology used shows that we can significantly reduce inventory in organizations.

5. Discussion on inventory levels in process industries

Ref. [18] wrote that on average, about 87.4 days of inventory in value (DIO) are being held across industries in the US. Ref. [3] also researched for the automotive, consumer electronics, primary metal and pharmaceutical industries and noted the median DIO from 1974 to 2009. He also wrote that while the major reductions have come from the consumer electronics and automotive industries in the last 40 years, process industries such as primary metals and pharmaceuticals have lagged behind (Figure 4.0).

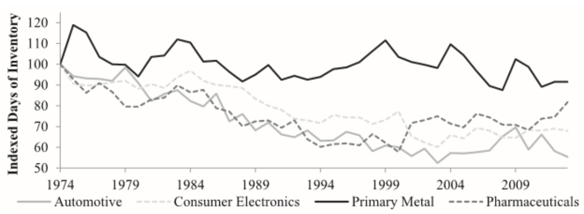

Figure 4. Days of inventory over 4 decades for automotive, consumer electronics, primary metal and pharmaceuticals.

The findings in this study showed that the organization concerned held 22.5 days of FG inventory and that the scenarios in the simulation could half the SID to 11.9 days if implemented. This will represent a substantial amount in inventory savings and the simulation results can also be applied to process industries globally but available capacity must be available for make to order (MTO) items, particularly for small batch capacity. With Industry 4.0 initiatives and manufacturing integration, the ability to produce 1 unit at a time for such make-to-order items could support the findings in this study.

The findings in this study can be used by supply chain managers to adopt inventory strategies that will reduce incidence of excess slow-moving inventory. Supply organizations may be able to respond to orders instead of keeping high inventory. Organizations may apply a make-to-order strategy if the customer is able to wait long enough. This is applicable in the case of McDonalds, where customers are able to wait just long enough in the queue from ordering of product to receiving the product during drive-ins, in particular. However, inventory related importance among companies tend to focus on product availability as a main objective [9] because consumers will not wait for the product when they attempt to make a purchase especially from supermarkets but consumers in make- to- order environments may wait for products after an order has been made, for example in laptop assembly or car manufacture. When finished goods inventory has reached zero, a supply chain manager may transfer inventory between warehouses or decide to produce a small batch. Small batch capacity for fast moving consumer products, example, beverages, tobacco, soft drinks have nowadays taken the form of vending machines and a real-world deployment in incorporating the Internet of Things (IoT) system for vending machines are in place which allows for mobile proximity payment for unattended point of sales.

4.0 Conclusion

This study aims to highlight to Supply Chain Managers in batch process industries that the simulation of inventory policies can yield different scenarios for an optimised inventory policy with lower days of inventory by installing responsive small batch capacity. It has been found that supply chain integration involving product and process relationships will improve delivery performance in a supply chain. [15].

4.1 Limitations and future research

The increase in small batch capacity and product dispensing from vending machines represents an investment and while advances have been made in Industry 4.0 for full supply chain integration, many small medium enterprises (SMEs) may not have the financial resources to implement innovative technology as there are considerable costs in implementing technology. This impedes small and medium-sized enterprises from accessing innovation [16] but the recommendations in this study will allow supply chain managers to effectively develop scenarios that will reduce slow moving inventory into make-to-order categories and keep a close eye on a manufacturing strategy to reduce or eliminate slow moving inventory. Greater understanding on how to reduce inventory waste will help mankind become thrifty and less wasteful [17]. In the area of food waste, for example, it was found that as much as around one third of all food produced for human consumption (equivalent to a staggering 1.3 billion tons), is lost or wasted annually [18] and the findings in this study will perhaps help reduce this statistic.

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