SJIF IMPACT FACTOR: 4.110 CRDEEPJournals
International Journal of Basic and Applied Sciences Singh et.al., Vol. 4 No. 3 ISSN: 2277-1921
International Journal of Basic and Applied Sciences Vol. 4. No. 3 2015. Pp. 108-117

Full Length Research Paper

Modification and Analysis of APIOBPCS Model using Inventory Control Best Practices for FMCG Sector

Roopa Singh[1*], Anurag Singh[2], and Ajay Agarwal[3]
[1& 3]Department of Industrial & Production Engineering, G. B. Pant University of Agriculture & Technology, Pantnagar, India.
[2] Cognizant Telecom Solutions, 24- Paraganas (S), West Bengal, India.

**Corresponding author: Roopa Singh*

Abstract
In manufacturing sector, inventory of raw materials and spare parts contributes a major expense towards the operating capital. Larger value of inventory is considered blockage of available capital for other developmental work along with the loss of interest on the blocked capital. Existing literature reveals that inventory is considered as negative parameter for whole of the manufacturing sector. A wide range of methodologies is proposed for inventory control and its management to reduce the cost involved. A wider coverage of existing literature is full of inventory control methodologies which can be isolated from other industrial activities. Implementations of these methodologies create a time gap between the analysis of results and their implementation in the industry. If result is observed to be affected by highly dynamic parameter like cost of the concerned raw material, the results obtained by analysis cannot contribute full advantage to the industry due to time gap in obtaining results and their implementation as well as due to inertia of work culture of the organisation. The whole scanned literature on inventory control practices can be divided in to three categories as EOQ based studies, application of optimization techniques, and application of control theory to make inventory control as on line control system. The present work is an attempt to consider the inventory control with the application of control system theory where obtaining feedback, drawing conclusions and implementation becomes an integral part of control without any time gap. The analyses of the results obtained by control system are also helpful in determining some objective oriented mathematical formulations used in decision making for the betterment of the performance. These formulations provide a criterion to prevent deterioration of situation beyond a certain level and then a platform to improve the situation. This can also be taken as a process of continuous improvement because precision of implementation of the proposed diagram can be improved for a particular industry by adding more and more past data as input information. Advantages of this work are clearly reported over the existing techniques in results and discussion.

Keywords: *Control theory, Inventory control, Manufacturing Sector, EOQ, Feedback*

Introduction

Development in inventory control practices till present can be categorized into three parts. First part consists of development of EOQ (Economic Order Quantity) model by Harris [Harris, 1913]. This model was limited to estimating various costs in an organization and developing various equations in order to balance all those costs. The concept of EOQ (Economic Order Quantity) was introduced to balance cost of holding too much stock against that of ordering in small quantities too frequently. EOQ is applied only when the demand is constant over the year and each new order is delivered in full only when inventory reaches zero. More research on this concept was done by Taft [Taft, 1918], Wagner [Wagner et.al. 1958], Erlenkotter [Erlenkotter, 1990].

Second part was the development of optimization techniques in the supply network. Inventory optimization is a method of balancing capital investment constraints or objectives and service level goals over a large assortment of stock keeping units while taking demand and supply volatility into account. Disney [Disney et. al. 1999] described a procedure for optimizing the performance of an industrially designed inventory control system. Genetic algorithm was proposed for optimizing system performance with the help of some parameters. Ho [Ho et.al. 2005] considered the effects of deteriorating inventory on lot-sizing in MRP systems. Three factors were considered for simulation, namely, rate of inventory deterioration, percent of periods with zero demand and setup cost. Schwartz [Schwartz et.al. 2000] presented a simulation based optimization framework involving SPSA (Simultaneous Perturbation Stochastic Approximation) as a means for optimally specifying parameters of various models for inventory management in supply chains under conditions involving supply and demand uncertainty.

Third part and recent innovation in this field is the application of control theory. John [John et.al. 1994] employed an ordering policy known as APIOBPCS (Automatic Pipeline, inventory and order based production control system) to minimize the variance of inventory levels with a sequence of forecast errors of demand over the lead time given. Hoberg [Hoberg et.al. 2006] applied linear control theory to study the effect of various inventory policies on order and inventory variability, which are key drivers of supply chain performance. Schwartz [Schwartz et.al. 2010] presented a fundamental and practical approach for applying controltheoretic principles to tactical inventory management problem in a production-inventory system which is the basic unit in a supply chain.

The application of electrical control theory enables the inventory control practices as a continuous control tool for instantaneous decision making for the appreciable economic advantages of the business organisations. Most of the work available is concerned with mechanical manufacturing industries and electronic industries. Negligible work has been done in the industries which consider agricultural produce as input raw material for their final product. It is important to mention that maintaining inventory is normally considered as a big evil, however, the case may be different in case of agricultural based industries like FMCG's and pharmaceutical industries. This is due to larger time-dependent fluctuation in the commodity costs of raw material of the industry. The cyclic variation in the cost of raw materials of such industry is an unavoidable and repeated phenomenon. Now a days, many industries are entirely dependent on agriculture as output of this sector is used as input (raw materials) in agro based industries like sugar industry, cotton industry, paper industry, tobacco industry, etc. Here, we can consider the leading companies of India (FMCG companies) like Dabur India Limited, Colgate-Palmolive, Jain Irrigations, Britannia Industries Limited, Nestle India, etc. These industries are totally based on the agricultural sector for their growth and profits. There are other emerging and global industries like Wal-Mart, McDonalds, Dominos, etc. that do not depend on agricultural sector directly. Instead, they buy processed raw material from the FMCG companies and prepare their own product.

The basic reason for selection of this area is union budget. A considerable amount of capital of these industries is blocked in their inventories. The research performed in the area of inventory control where optimisation has been merged with electrical control theory as described in the paper presented by Disney et.al. [Disney, 2000] is limited to mechanical and electronics industries and they have not considered cost factor in their work. Since, agriculture forms a major portion of Indian economy, we need to focus on the cost factor related to agriculture and hence, we proposed a enhanced model that includes the cost factor as a parameter of inventory control, taking the model presented by Disney et.al [Disney, 2000] as the base model. This model is applicable for make-to-store industries. Since, a major budget of the Indian economy depends upon agricultural produce, and FMCG sector is continuously growing, the present work is being taken up to review and update the inventory control practices of the industries where there is a significant impact of commodity cost on their performance. Continued application of control theory makes the decision making highly instantaneous without losing any portion of the proposed profit due to late implementation of the determined decision. The work also replaces the quantitative values of the inventory related error and WIP related error with their monetary values making the decision-making fully target oriented.

Methodology

Application of Electrical Control Theory

A control system is an interconnection of components forming a system configuration that will provide a desired system response. The basis for analysis of a system is the foundation provided by linear system theory, which assumes a cause–effect relationship for the components of a system [Introduction to control systems, 2012]. Control system describes the behaviour of a system by differential equations. The differential equations may be ordinary differential equations or difference equations. The control system can be classified as open loop control system and closed loop control system.

Open loop control system

Open loop control system is also known as control system without feedback or non feedback control systems. In this system, the control action is independent of the desired output. The output is not compared with reference input [Saeed, 2012].

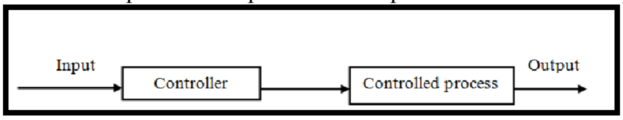

Fig 1: Open Loop Control System

The component of the open loop systems are controller and controlled process. The controller may be anything depending upon the system. An input is applied to the controller and the output of the controller is fed into controlled process which finally gives the desired output. An open- loop control system utilizes an actuating device to control the process directly without using feedback.

Closed loop control system

Closed loop control systems are also known as feedback control systems. In this system, the control action is dependent on the desired output. If any system has one or more feedback paths, it forms a closed loop system. The output is compared with the reference input and error signal is produced which is fed to the controller to reduce the error and desired output is obtained. [Saeed, 2012]

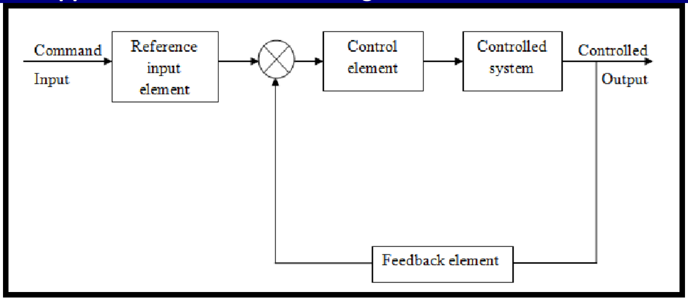

Fig 2: Closed Loop Control System

The various components of closed loop system are:
Command: The command is the externally produced input and independent of the feedback control system.
Reference input element: This produces the standard signals proportional to the command.
Error detector: The error detector receives the measured signal and compares it with reference input. The difference of two signals produces the error signal.
Control element: This regulates the output according to the signal obtained from error detector.
Controlled system: This represents what we are controlling by the feedback loop.
Feedback element: This element fed back the output to the error detector for comparison with the reference input.

Feed-Forward Connection
Feed-forward is defined as an element or pathway within a control system which passes a controlling signal from a source in its external environment, often a command signal from an external operator, to a load elsewhere in its external environment. A control system which has only feed-forward behaviour responds to its control signal in a pre-defined way without responding to how the load reacts, the load is considered to belong to the external environment of the system.

In a feed-forward system, the control variable adjustment is not error-based. Instead it is based on knowledge about the process in the form of mathematical model of the process and knowledge about or measurements of the process disturbances. [Saeed, 2012]

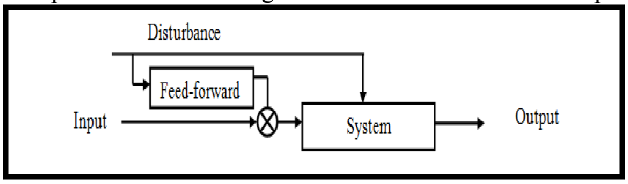

Fig 3: Feed-Forward Connection

Laplace Transform
The Laplace transform can be used to solve differential equations. Besides being a different and efficient alternative to variation of parameters and undetermined coefficients, the Laplace method is particularly advantageous for input terms that are piecewise-defined, periodic or impulsive. The direct Laplace transform or the Laplace integral of a function f (t) defined for $0 \le t \le \infty$ is the ordinary calculus integration problem

$$\int_0^\infty f(t)e^{-st}dt$$

succinctly denoted L(f(t))in science and engineering literature. The L- notation recognizes that integration always proceeds over $t = 0$ to $t = \infty$ and that the integral involves an integrator $e^{-st}dt$ instead of the usual *dt*. These minor differences distinguish Laplace integrals from the ordinary integrals. [Saeed, 2012]

Transfer Function
The transfer function is defined as the ratio of Laplace transform of the output to the Laplace transform of input with all initial conditions as zero.

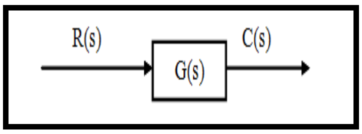

Fig 4: Open Loop Control System

Consider the block diagram of open loop control system where R(s) and C(s) are the Laplace transform of input and output respectively, then the transfer function G(s) can be expressed as

$$G(s) = \frac{C(s)}{R(s)}$$

Consider the block diagram shown below:

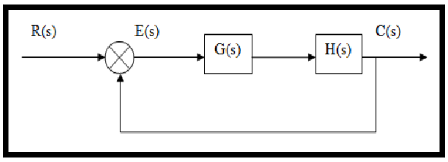

Fig 5: Closed Loop Control System (Series Connection)
This is the standard cascade compensation, unity feedback system.

G(s) = Transfer function
H(s) = Compensate transfer function
R(s) = Reference input
C(s) = Output
E(s) = R(s) – C(s) = Error signal or actuating signal

The block diagram represents the equations:

$$C(s) = E(s)\,G(s)\,H(s)$$
$$E(s) = R(s) - C(s)$$
$$= R(s) - E(s)\,G(s)\,H(s)$$

Therefore,

$$E(s) = \frac{R(s)}{(1 + G(s)\,H(s))}$$

And

$$C(s) = \frac{G(s)\,H(s)\,R(s)}{(1 + G(s)\,H(s))}$$

The transfer function G(s) H(s) / (1+G(s) H(s)) is called the closed loop transfer function. The transfer function 1 / (1+G(s) H(s)) is called the system sensitivity function. In some cases the compensator H(s) might be given in the `feedback path' instead of in cascade with the plant. [Saeed, 2012]

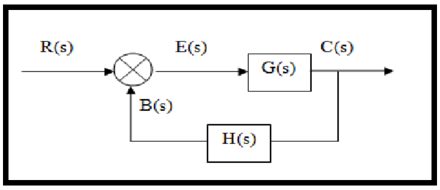

Fig 6: Non-Unity Feedback System

This forms a non-unity feedback system. In this case, the open loop transfer function

$$G(s)\,H(s) = \frac{B(s)}{E(s)}$$

The actual signal is

$$E(s) = R(s) - B(s)$$
$$= R(s) - H(s)\,C(s)$$

In this case that the actuating signal is no longer the same as the error signal, R(s) - C(s). In fact, the error signal is not physically present in the block diagram in the case of non-unity feedback. It is easy to show that the closed loop transfer function now is

$$\frac{G(s)}{(1 + G(s)\,H(s))}$$

And the sensitivity function is the same.

Block diagram reduction

A general linear control system may be built up from many interconnected subsystems, each of which is a system by itself, and, hence, represented by a transfer function. We need ways to reduce a complicated block diagram to a simpler form.

1) Series (cascade) connection

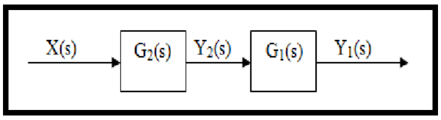

Fig 7: Series Connection

This is equivalent to

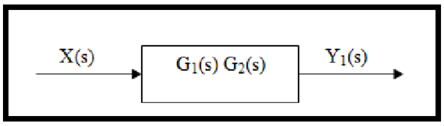

Fig 8: Equivalent Diagram

The original block diagram represents the equation

$$Y_2(s) = G_1(s)\, X(s)$$
$$Y_1(s) = G_2(s)\, Y_2(s)$$

Therefore,

$$Y_1(s) = X(s)\, G_1(s)\, G_2(s)$$

2) Parallel connection

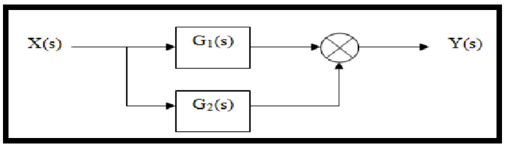

Fig 9: Parallel Connection

$$Y(s) = G_1(s)\, X(s) + G_2(s)\, X(s)$$
$$= (G_1(s) + G_2(s))\, X(s)$$

Feedback connection

Unity feedback

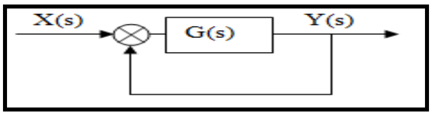

Fig 10: Unity Feedback Connection

Is equivalent to:

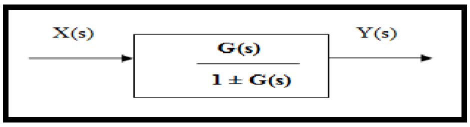

Fig 11: Equivalent Diagram

Non unity feedback

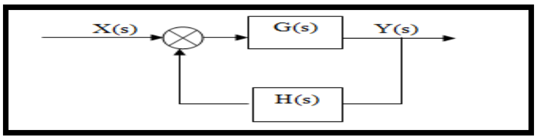

Fig 12: Non-Unity Feedback Connection

Is equivalent to

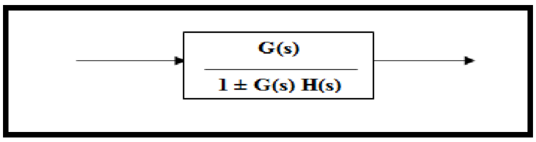

Fig 13: Equivalent Diagram

Procedure of Merger of Control System with Inventory Optimization Method

According to Burbidge's Law of Industrial Dynamics, "if demand is transmitted along a series of inventories using stock control ordering, then the amplitude of demand variation will increase with each transfer" [Burbidge, 1984]. Control system theory has lessened the efforts required in the modelling and analysis of production-inventory system dynamics with the use of frequency domain calculation. Mathematical models based on average or steady-state conditions are insufficient when dealing with dynamic situations faced by production-inventory systems in current business environments. Therefore, the use of mathematical tools based on control theory to handle time-varying phenomena has been reinvigorated in order to accommodate these new needs. The following characteristics will help in understanding the procedure of integration of control system with inventory optimisation method in a better way:

- Order decision rules in inventory theory are based on one or more of three fundamental information flows, namely demand, physical inventory level and work-in-progress.
- In control systems, the information is of two basic types, feedback coming from within the system and feed-forward coming from outside.
- In general, inventory and work-in-progress are transmitted as feedback information, whereas demand has a feed-forward character.
- The inventory level monitored usually includes physical on-hand-stock as well as on-order-stock (work-in-process, WIP), which is delivered to the system after some lead time. The sum of on-hand- stock and on-order-stock is referred to as the inventory position.
- WIP (work-in-process) is the cumulative difference between the order rate and the completion rate of production.
- The demand rate is used for generating a forecast of future demand. Forecasting is considered to be an additional input to the order policy.
- Properties of demand rate and lead time are also inputs to the control policy for establishing an appropriate safety stock level.

Following procedure explains the integration of control theory with inventory optimisation method:

- At the beginning of each period, the demand forecast is computed using exponential smoothing along with the selection of an appropriate smoothing factor.
- Then the target inventory is computed by extending the demand forecast over the inventory cover time.
- Next, the inventory error is computed as the target inventory level minus the current inventory level. Then the order is placed.
- The order quantity equals the inventory error plus the latest demand forecast.
- Finally, the order that was placed earlier arrives and demand occurs and is filled to the extent possible. Excess demand is backordered.
- Now, we represent the system in frequency domain by using Laplace transform and transfer function.
- The properties of the system are characterized in control theory by its transfer function which represents the system output in relation to its input in the frequency domain.
- Transfer function of orders in response to customer demand is denoted by a different notation and transfer function of inventory levels in response to customer demand is denoted by another notation.
- The Final Value Theorem is also applied to evaluate the steady-state errors.

The updated work has been described in the next section.

Modified APIOBPCS Model

The proposed work is an extension of the Automatic Pipeline, Inventory and Order Based Production Control System (APIOBPCS) model developed earlier as described previously. The given work converted the inventory related error and work-in-progress (WIP) related error into monetary value. Inclusion of cost factor in the developed model is the basis for this conversion. Firstly, the desired inventory holding (DINV) which is the raw materials inventory has been converted into a monetary value by multiplying it with commodity cost and amending it with a constant 'K8'. 'K8' is driven by some internal factors of the organization like process related factors that prevents whole DINV from being converted into some monetary value. Similarly, the actual inventory holding (A) which is the finished products inventory has been converted into a monetary term by multiplying it with the commodity cost (which is slightly greater than the commodity cost of DINV due to addition of processing charges, etc in A) and a constant 'K9'. 'K9' is also driven by some internal process related factors that prevents conversion of whole DINV into some monetary value. The used nomenclature in the model is detailed below:

Notations:

K1	*Process dependant multiplier (K1<= 1)*
K2	*Factory sales averaging time*
K3	*Inventory adjustment time*
K4	*Mathematical operator*
K5	*Production WIP (work in progress) gain (Tp)*
K6	*Work in progress time (Tw)*
K7	*Conversion factor that converts actual inventory holding into monetary value* M_{ai}

K8 *Conversion factor that converts desired inventory holding into monetary value* M_{di}
K9 *Constant*

AVCON *Average consumption*
Cons. *Forecasted or market demand*
E *Error in inventory holding*
e *Error in work in progress*
O *Order rate*
C *Completion rate*
A *Actual inventory holding*
WIP *Work in progress*
DINV *Desired inventory holding*
DWIP *Desired work in progress*
M_{di} *Capital value blocked in desired inventory holding*
M_{ai} *Capital value blocked in actual inventory holding*
V_{ai} *Market value of actual inventory holding*
S.P. *Selling price of finished products inventory*
C. C. *Commodity cost*
G *Gain due to difference between capital value blocked in actual inventory holding and market value of actual inventory holding*

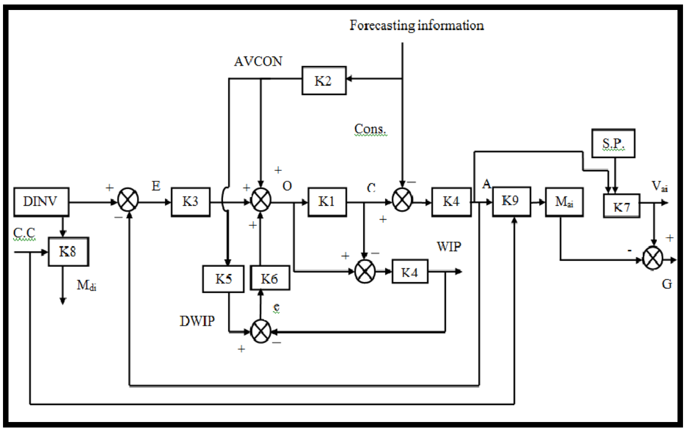

Fig 14: Modified APIOBPCS Model

The notation 'M_{di}' in the given figure represents the capital blocked in desired inventory holding (DINV). Likewise, 'M_{ai}' represents the capital blocked in actual inventory holding (A). The given figure follows make-to-store policy where loss due to stock out of final product is accessed much more than the loss due to waste of final product due to their over storage time as well as cost of storing excess inventory is also comparatively affordable. This may lead to the risk of losing some customers forever. The figure is analyzed with the application of control theory and following equations are derived:

Error in the inventory is considered as difference of actual inventory with the desirable inventory level. Negative value of 'E' indicates excess inventory and it is supposed to be compensated at the level of order rate.

E = DINV – A (4.1)

Error in pipeline or production flow is considered as difference of work-in-progress with desirable work-in-progress.

e = DWIP – WIP (4.2)

Order rate is the schedule of production on the shop floor which is to be achieved. It is the combined output of three inputs that have been manipulated in the following way:

The first input is the product of error in inventory and 'K3' (E * K3). 'K3' is the inventory adjustment time and covers the production lead time.

Second input is the product of error in WIP and 'K6' (e * K6).

Third input to the order rate is the product of consumption or market demand with a constant, 'K2' (Cons. * K2). 'K2' is used to average out the fluctuating values of forecasting up to some extent.

The sum of above inputs gives the output as order rate or the schedule of production target to be achieved.

Order rate = Sum of above inputs

O = E * K3 + e * K6 + Cons. * K2 (4.3)

The error should always be positive. In case it is negative, it should be denoted with '-'sign. 'K6' is a factor which adjusts the surplus or short WIP inventory with respect to maintain the actual inventory at its desired value. It depends upon process related parameter and process lead time. The completion rate which is considered as the actual production rate per unit time is the product of order rate and a constant, 'K1'. 'K1' is a process dependant multiplier which should be always less than or equal to 1. Value of 'K1' will be much lesser than 1 if there is maintenance problem in setup or more rejectable produce is being obtained. Higher the value of 'K1' (near to 1), lesser will be WIP which is desirable.

$$C = O * K1$$
$$= (E * K3 + e * K6 + Cons. * K2)\, K1 \quad (4.4)$$

'K2' is an operator used to convert variable forecasting information to relatively consistent value of 'AVCON'. 'K3' and 'K6' covers production lead time.

Equation (4.4) reveals that 'K1', 'K3' & 'K6' have mutual qualitative dependency.

'K4' is a mathematical operator which converts a variable completion rate to actual inventory per unit time. Completion rate should be less than consumption in order to make actual inventory positive.

$$M_{ai} = A * C.\,C. * K9 \quad (4.5)$$

Capital value blocked in actual inventory i.e. 'M_{ai}' is the product of quantity of 'A', commodity cost of 'A' and a factor 'K9'.

$$M_{di} = DINV * C.\,C. * K8 \quad (4.6)$$

Capital value blocked in desired inventory i.e. 'M_{di}' is the product of quantity of 'DINV', commodity cost of 'DINV' and a factor 'K8'.

$$V_{ai} = A * S.\,P. * K7 \quad (4.7)$$

'V_{ai}' represents the market value of 'A' which is the product of quantity of 'A', selling price of finished goods in 'A' and a factor 'K7'. 'K7' is a multiplier which multiplies actual inventory that can be sold in the market at the current selling price and is affected by the selling price of same commodity present in the market.

Gain is the difference between 'V_{ai}' and 'M_{ai}' i.e. market value of 'A' and capital blocked in 'A'.

$$G = V_{ai} - M_{ai} \quad (4.8)$$
$$= A * S.\,P. * K7 - A * C.\,C. * K9$$
$$= A * (S.P. * K7 - C.C. * K9)$$
$$\frac{G}{A} = K'7 - K'9 \quad (4.9)$$

The given equation represents gain with respect to 'A' in terms of monetary units of 'A'. Selling price is merged with 'K7' and replaced by 'K'7'. Similarly, commodity cost is merged with 'K9' and replaced with 'K'9'.

Now,

$$A = K4 * (C - Cons.) \text{ and, } C = O * K1$$

Therefore,

$$A = K4 * (O * K1 - Cons.) \quad (4.10)$$

Also,

$$M_{ai} = A * K'9$$
$$= K4 * (O * K1 - Cons.) * K'9$$

And,

$$V_{ai} = A * K'7$$
$$= K4 * (O * K1 - Cons.) * K'7$$

And,

$$O = E * K3 + e * K6 + CONS. * K2$$

Therefore,

$$G=K4*[(E*K3+e*K6+Cons.*K2)*K1-Cons.)]\,[(K'7-K'9)] \quad (4.11)$$
$$G=K4\,(K'7-K'9)\,[EK3K1 + eK6K1 + Cons.\,(K1K2 - 1)] \quad (4.12)$$

Taking Cons. As 'P' and expressing 'E' and 'e' as % of consumption ($E=\alpha*P$, $e=\beta*P$), we get

$$G = K4\,(K'7-K'9)\,[EK3K1 + eK6K1 + P\,(K1K2 - 1)]$$
$$G = K4\,(K'7 - K'9)\,[\alpha K3K1 + \beta K6K1 + K1K2 - 1]\,P$$
$$G = K4\,(K'7 - K'9)\,[EK3K1 + eK6K1 + E/\alpha\,(K1K2 - 1)] \quad (4.13)$$

Again, from eqn. (4.7), $\frac{C}{K1} = E * K3 + e * K6 + Cons. * K2$

$$Cons. * K2 = \frac{C}{K1} - E * K3 - e * K6 \quad (4.14)$$

Results

The proposed modified model APIOBPCS along with its mathematical analysis has already been described in the previous section. The results obtained from the analysis of this modified model are formulated in terms of industry related parameters with an intention to find out the performance improvement strategy of the business.

It is desired to keep the value of DINV larger, only then the value of 'A' will be larger and large value of 'A' will be responsible for gain due to appreciable value of (K'7 - K'9). This also confirms the fact that raw material, which may be an agricultural produce, should be purchased at its harvesting time at the least cost for whole of the year

In the given model, ‘E’ which is the error produced due to difference in actual inventory holding and desired inventory holding should be considered from other point of view as a constraint and a critical parameter. That is its value should not exceed a certain limit, the amount which should be consumed before its expiry period.

Difference in actual value of work in progress inventory and its desired value is shown by ‘e’ which is the error produced due to capability of organization to accommodate. Any value of ‘e’ clearly indicates that order rate issued to the shop floor could not be completed as per schedule. So, the desirable value of ‘e’ should be zero provided that there is no planning to store the semi-finished goods on the shop floor due to any pre-determined purpose. The block diagram of the proposed model clearly indicates merger of ‘e’ to order rate for its elimination as far as possible.

Equation (4.14) in the previous section tells about the existence of average consumption (AVCON) in the system and it can be seen that average consumption will exist till

$$\frac{C}{K1} \gg E * K3 + e * K \qquad (4.15)$$

Where; ‘K1’, ‘K3’ & ‘K6’ are the industry related factors. ‘K3’ and ‘K6’ directly depends on the fact, ‘according to production lead time, how the ‘E’ and ‘e’ will affect the value of ‘O’. The value of ‘K1’ depends upon the efficiency of operation of production system and its maximum value can be 1 as ‘C’ can never be more than ‘O’. To ensure the market demand, it is recommended to keep eye upon $[\frac{C}{K1} – E * K3 – e * K6]$. Lower value of this factor is an indicative of loss of market demand and we know that in any business loss of market demand occurs gradually. So, if this value goes less than a particular pre-fixed value, lower market demand should be taken up as an alarming situation. This fact goes in the favour to reduce the value of ‘K1’ but too much reduction in the value of ‘K1’ is not advisable; otherwise, work in progress inventory will increase. So, left hand side of the eqn. (4.15) should be adjusted to increase at the same time management should attempt to reduce the value of left-hand side of same eqn. to maintain a wider gap between two sides. Accordingly, industry related decision should be taken in the light of above discussion.

The monetary gain due to the inventory and gap between the selling price and cost of raw material is given by eqn. (4.12). The variation of Gain with respect to forecasted demand (Cons.) and gap between selling price and commodity cost (K'7 - K'9) is plotted in the 3-D graph shown in Fig 15.

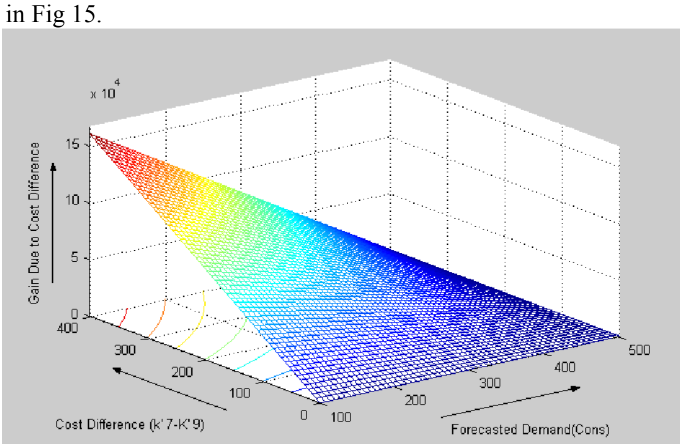

Fig 15: Variation of Gain w.r.t Forecasted Demand (Cons.) and Gap (K'7 - K'9)

Gain is found to be more influenced by the price gap as compared to forecasted demand (Cons.). It indicates that business strategy should be focused upon the actions responsible for higher values of (K'7 - K'9) maintaining the value of ‘Cons.’ to a particular level. The value of ‘K'7’ is almost beyond the control of the industry as it is decided by the market competition. So, whole stress should be upon lowering the value of ‘K'9’ by proper vendor development and hiring the crop much before its harvesting time. When there is a saturation in further improvement (K'7 - K'9), the value of ‘Cons.’ can be improved by expanding the market share.

On the basis of eqn. (4.8) gain is the difference between capital value blocked in actual inventory holding and market value of actual inventory holding. Capital value blocked in actual inventory holding is the money that we spent on the product and its inventory. Market value of actual inventory is the real value of product. Gain depends upon the commodity cost of finished products inventory and selling price of finished products. Eqn. (4.9) shows that difference between selling price (merged with ‘K7’ and replaced by ‘K'7’) and commodity cost (merged with ‘K9’ and replaced by ‘K'9’) keeps on changing throughout the year, so gain keeps on increasing. Therefore, gain rises due to gap between ‘K'7’ and ‘K'9’ which is represented by eqn. (4.12).

Actual inventory holding is responsible for gain and it depends on the values of its processing factor. Actual inventory is obtained after the smoothing of consumption (large fluctuations in market demand) based on forecasting information. Eqn. (4.10) implies that actual level of inventory is obtained by smoothing with the help of a controller 'K4' which eliminates frequent fluctuations in the market demand. The upper value of actual inventory should be fixed to avoid loss due to wastage of finished products inventory. As the value of actual inventory goes beyond a certain value, its processing factor comes down adversely.

The actual inventory of finished products cannot be fully converted into monetary terms by multiplying it directly with the commodity cost. So, a constant 'K9' is required which shows the effect of processing factors that prevent the full conversion of actual inventory into monetary value which is represented by eqn. (4.5). In the same way, it is not necessary that the whole inventory of finished products is sold in the market. There are some factors that prevent the finished products from being fully sold in the market. Therefore, to get the market value of actual inventory of finished products, it is multiplied with the selling price of the product along with a constant, 'K7'. This has been shown by eqn. (4.7). 'K7' represents the factors that prevent the entire inventory of finished products from being sold in the market. Selling price of a product is affected by the selling price of same commodity manufactured by a different company, present in the market.

Referring the eqn. (4.12) the controller 'K1' representing the efficiency of production system has an interacting effect with the cost difference (K'7-K'9). However, 'K'7-K'9' is a major contributor after the "Cons" to the gain. So, if there is any reduction in the value of 'K1' happens, it reduces the gain doubly, due to its own reduction and its impact on the value of 'K'7-K'9'. There is a need to find the optimum value of 'K1', that may be different for different industries of the same sector, and management discussion should be focused upon the maintaining consistency in its value forever.

Conclusions

The present work is based upon the application of control theory in the inventory control practices due to its advantage of negligible time gap between decision making and its implementation. This work uses the monetary value conversion of actual inventory and work-in-process inventory which is considered in the analysis and discussion along with other industry related parameters for better business strategy formulation in the industry. The objective specific mathematical formulations (eqn. 4.15) as a function of industry related controlling parameters provide opportunity of monitoring the performance of organization. They also act as an alarming factor which is used to restrict the performance from deterioration. The modified model also helps in identification of critical controlling factors on the basis of their direct and indirect effect on business performance. It is also helpful in decision-making related to purchase of raw material for economic advantage applicable to industries belonging to FMCG's and pharmaceutical sector. Overall, the research is helpful in industrial decision-making and their implementation for continuous improvement with increased frequency to accommodate the instantaneous changes as real time information and so it can be described as on-line control of business performance.

References

Burbidge, J. L(1984). Automated production control with a simulation capability. *Proceedings of IFIP Conference WG5-7*, Copenhagen

Disney S. M., Naim M. M., Towill D. R. (2000). Genetic algorithm optimization of a class of inventory control systems, *Int. J. Production Economics* 68 (2000) 259-278.

Erlenkotter D., 1990. Ford Whitman Harris and the Economic Order Quantity Model. Operations Research, *In*: Vol. 38, No. 6. (Nov. - Dec., 1990), pp. 937-946.

Harris, F.W., 1913. How many parts to make at once. Factory, the Magazine of Management 10(2), 135-136,152.

Ho, Johnny. C., Solis, Adriano. O., Chang, Yih-Long (2005). An evaluation of lot-sizing heuristics for deteriorating inventory in material requirement planning systems. *Computers and operations research* 34 (2007) 2562-2575.

Hoberg, Kai., Bradley, James. R., Thonnemann, Ulrich. W. (2006). Analyzing the effect of the inventory policy on order and inventory variability with linear control theory. *European Journal of Operational Research* 176 (2007) 1620–1642.

John, S. Naim, M. M. and Towill, D. R., 1994, Dynamic analysis of a WIP compensated decision support system. *International Journal of Manufacturing System Design*, 1(4), 283-297.

Saeed Syed Hasan, Control systems, (New Delhi: S. K. Kataria & Sons, 2012), p. 1.

Schwartz, Jay. D., Rivera, Daniel. E. (2010). A process control approach to tactical inventory management in production-inventory systems. *Int. J. Production Economics* 125 (2010) 111-124.

Schwartz, Jay. D., Wang, Wenlin, Rivera, Daniel. E. (2006). Simulation-based optimization of process control policies for inventory management in supply chains. *Automatica* 42 (2006) 1311-1320.

Taft, E. W. (1981). The Most Economical Production Lot. *Iron Age* 101, 1410-1412.

Wagner, H. M. And Whitin, T. M., (1958). Dynamic Version of Economic Lot Size Model. Mgmt. Sci., 89-96.

www.site.uottawa.ca/~rhabash/ELG4152LN01.pdf. Introduction to Control Systems (2012). 25-04-2013