

# Inventory Management in Closed Loop Structure Using KPIs

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## Abstract

Inventory management is one of the major function of the supply chain. It is indeed considered as a serious issue that greatly affects the company performances. Due to the complexity of the inventory process and its resulting operations. It is difficult to find an effective way to extract relevant information from a large amount of data and thus make strategic decisions based on the meaningful and accurate information. The manager goal is also to find the right balance between an optimal stock level and an acceptable level of service. This paper proposes closed-loop control of an inventory process using Key performance indicators (KPI's). Based on the comparison between measured KPI's and target KPI's, solutions are proposed to improve the management of the stock process.

**Keywords:** Closed loop control; inventory management; key performance indicator; inventory turnover; service level

## INTRODUCTION

Recently, industrials have shown a keen interest to efficient supply chain management. This does not come as a coincidence since nowadays markets have become more dynamic due to rapid changes in customer requirements. These rapid changes have increased the importance for companies to ensure materials and information flow smoothly between the actors in a supply chain. For years, researchers and practitioners proposed various methods of modeling supply chains. Most of these models are static, which is insufficient to represent the dynamic characteristics of the supply chain and to describe, analyze and find solutions for major problems like demand variability, lead-time delays, and sales forecasting.

Dynamic analysis and design of supply chain systems have attracted a lot of attention, especially from the academia. Some well-written papers provide a review and even propose solutions to demand variability problems.[2] [4]

Supply chain based on dynamic analysis modeling was subject to several modifications and improvements [11]. One can

mention some of these works like a classic Laplace transform, used to analyze simple production-inventory systems [9]. One can mention as well Towill (1982) who presented the Inventory and Order Based Production Control System (IOBPCS) in a block diagram form and analyzed every part of it using transfer function techniques. Improvements have been extended to discrete time systems [16]

In order to remain competitive and gain advantages, continuously improving performances of the dynamic supply chain in companies has become a critical issue whether for suppliers, manufacturers or retailers. Indeed, the establishment of appropriate performance measures is one of the most important elements in supply chain analysis. Being able to measure supply chain performance is important since it leads to a greater understanding of the supply chain and provides important feedback on the improvement progress [10]. The measures that help a company evaluate their performance progress in everyday work are often referred to as key performance indicators (KPIs), which are crucial for optimizing supply chain performance. By monitoring these KPIs, managers can better understand trends, identify potential problems and make fast and effective decisions.

Indeed, making strategic decisions does not seem an easy task, especially when it comes to one of the major functions in the supply chain: Inventory. Although the latter is seen as an issue that greatly impacts the company performance, industrial market evolutions make the regulation and optimization of inventory flow an unreachable complex challenge, and therefore it is difficult to find an efficient way to Extract relevant information from a large amount of data [3].

In order to find a balance point reconciling stocks and level of service in a context of cost control, one proposes the use of inventory KPI's in a closed-loop control structure and propose appropriate thus control strategies.

The paper is organized as follows: Section 2 is an introduction to dynamic systems and their fields of use as well as a dynamic description of the inventory system; In section 3 the inventory system approach in a closed loop structure using KPI's is

explained; The paper ends with section 5, which details various control strategies in a case study.

## DESCRIPTION OF INVENTORY SYSTEM

An inventory is a stock of goods which is held or stored for the purpose of the future sale or production [18]. The inventory system can have one or multiple supplier sources (supplier<sub>i</sub> with  $i=1\dots n$ ) and one or multiple retailers (Retailer<sub>j</sub> with  $j=1\dots m$ ). In the system shown in figure 1, distribution center is an intermediary between suppliers and retailers, which are connected by material and information flows. Inventories are held, to satisfy downstream demand. The main purposes of inventory management in the industry are both, establishing appropriate supply policies by placing economic quantity orders and reducing storage cost while simultaneously maintaining an acceptable stock level.



Figure 1: Inventory system

The rapidly growing field of system dynamics is increasingly seen as the best hope for dealing with multiple-feedback-loop, nonlinear systems that extend across many different intellectual disciplines [13]. Dynamic systems are particularly powerful in analyzing the behavior of systems, whether social, economic or ecological. This method is also effective in supporting a strategic point of view so that it matches the concerns of decision makers. Based on modeling the underlying forces of the future evolution of a system, the analyst proposes guidelines about the way evolution can be managed so that the system can be robust in terms of ability to overcome possible constraints. Indeed, the behavior of a system over time and new decisions to be taken are significant management problems, which require the analyst to focus on how a system reacts to dynamic forces and how these reactions affects its behavior in the future.

Dynamic systems are used in a diagram form as a thinking and understanding support [14]. They are also used to convert these diagrams into a simulation and optimization model in order to propose management strategies.

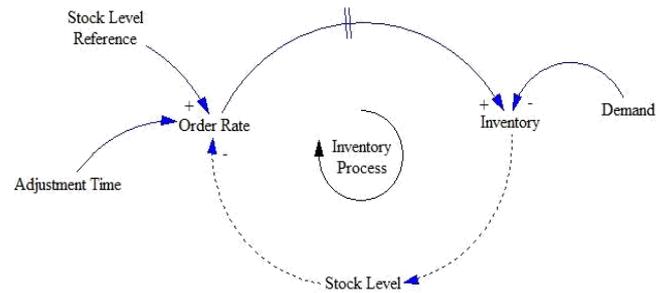


Figure 2: Causal diagram of the dynamic behavior of the stock

The causal diagram in Figure 2 describes the dynamic behavior of the inventory system. The order rate is the input of the system; it represents the manipulated variable that triggers the process. The difference between the stock level reference and the actual stock level represent output error. Demand is considered as a system disturbance.

## INVENTORY MANAGEMENT IN CLOSED LOOP USING KPI'S

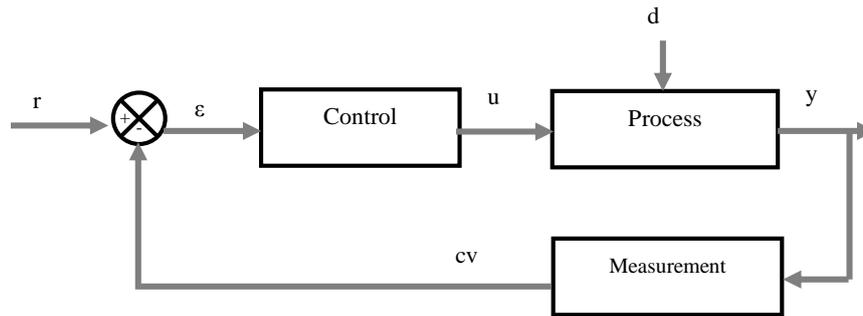
### Inventory management in closed loop approach

For an efficient and responsive supply chain, two tasks must be considered: (1) the transformation of the company's strategic priorities into concrete results and (2) control of the company flow.

For this reason, industrial managers must have a complete, end-to-end view of all processes, including all stakeholders, and therefore rely on significant and accurate information to make strategic decisions.

Indeed, the main purpose of inventory manager is to achieve an acceptable service level by meeting customer demand while maintaining a stable stock level so that there is no stock shortage or overstocking.

It is clear that managers intuitively practice closed-loop control of the inventory process. They observe the behavior of the stock system and its parameters: stock level, delivered quantity, inventory costs ... and compares it to the desired value. In the case where the output is different from the desired value, adjustments to the input of the system are required to achieve the set point. The block diagram of fig.3 shows the closed-loop control structure of an optimal process management. The input  $u$  and output  $y$  of the process are respectively called manipulation variable and measured variable. The variable compared to the reference value  $r$  is called the  $cv$  control variable. Based on the resulting error of this comparison, we propose appropriate control strategies.



**Figure 3:** Closed loop structure

- u Input: manipulated variable
- y Output: measured variable
- r Reference variable
- cv Control variable
- d Disturbance

### Inventory key performances indicators

Due to the complexity of the inventory process and its resulting operations, it is difficult to find an effective way to extract relevant information from a large amount of data. The solution is to define a set of measures, also known by the KPI: KPI that represents a set of variables that quantitatively expresses the efficiency or effectiveness of part or all of a process or System, Standard or Target "[10]. One can clearly say that the key performance indicators are used to convert strategic objectives into measurable variables.

Inventory performance evaluation is mainly based on two criteria: The first one consist of controlling stock level, and the most frequently used KPI, in this case, is *inventory turnover*. The second criteria are about the service quality provided by inventory process. In this context, we commonly use *customer service level KPI*.

- ✓ **Inventory turnover (InvT):** This KPI indicates whether the company is using the inventory. It is the number of times the inventory has been consumed or turned over during a specified period, usually a year [5]:

$$InvT = \frac{\text{Cost of Goods sold}}{\text{Average Inventory}}$$

- ✓ **Service level (SL):** This KPI is defined as the probability of being able to meet customer demand without back order or lost sale during a given period [5]:

$$SL = \frac{\text{Value of satisfied orders}}{\text{Value of total orders}}$$

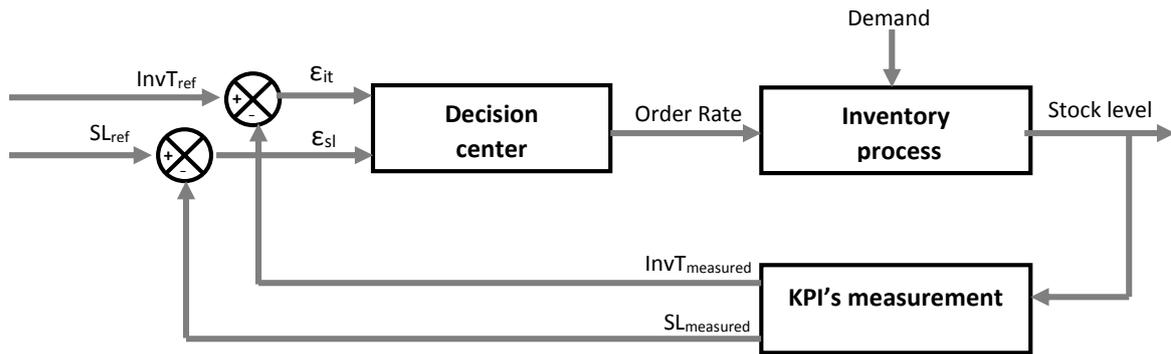
### STUDY CASE

#### Application

In this work, we develop the idea of a closed loop inventory control using inventory KPI's. The inventory process in the example of figure 4 has an output variable represented by the actual stock level, where the control variables of the system are represented by service level and inventory turnover.

These are the KPI's which will be compared to the desired values. The latter are defined at the high strategic level, with the collaboration of the inventory managers. The order rate is the required manipulated variable to improve the inventory process behavior.

Based on the resulting error  $\epsilon$  of the comparison between the actual measurements and desired set points, the control part represented by the decision center proposes improvement actions to reduce the error. Indeed, a detailed article-by-article analysis will identify short- and medium-term operational solutions to regulate stock levels without degrading the service level or even, in most cases, improving it. These solutions will thus help improve the inventory management process through its input variable defined by the order rate. This is the manipulation variable required to improve the behavior of the stock process and thus regulate the stock level.



**Figure 4:** Closed loop structure using stock turnover KPI and service level KPI

**Decision center flowchart**

Making decisions involves choosing the optimal solution among several alternatives. The difficulty of decision-making lies precisely in the choice between these different alternatives while maintaining a low level of uncertainty. However, very few decisions are taken with absolute certainty since the knowledge of the various alternative solutions remains incomplete. This is why we used the flowchart approach in this work. The flowchart is considered a recognized method for documenting processes [7]. We have adopted it to solve problems related to inventory management, evaluate and identify the best possible alternative [17].

The flowchart in Figure 5 details the decision center and the procedure to follow in case the KPI's references have not been

reached. This procedure is declined in the form of solutions. Generally, a low turnover rate can be interpreted as a poor sale, an overstock and/or obsolescence of some stored items. Although a high inventory turnover also implies a better flow of outputs, it may also show an inconsistency in the inventory. On the other hand, a low service level would reflect a problem of the adopted procurement policy.

**Discussion**

There are several improvement actions that improve both indicators. The proposed solutions in the flowchart have been developed in the table below:

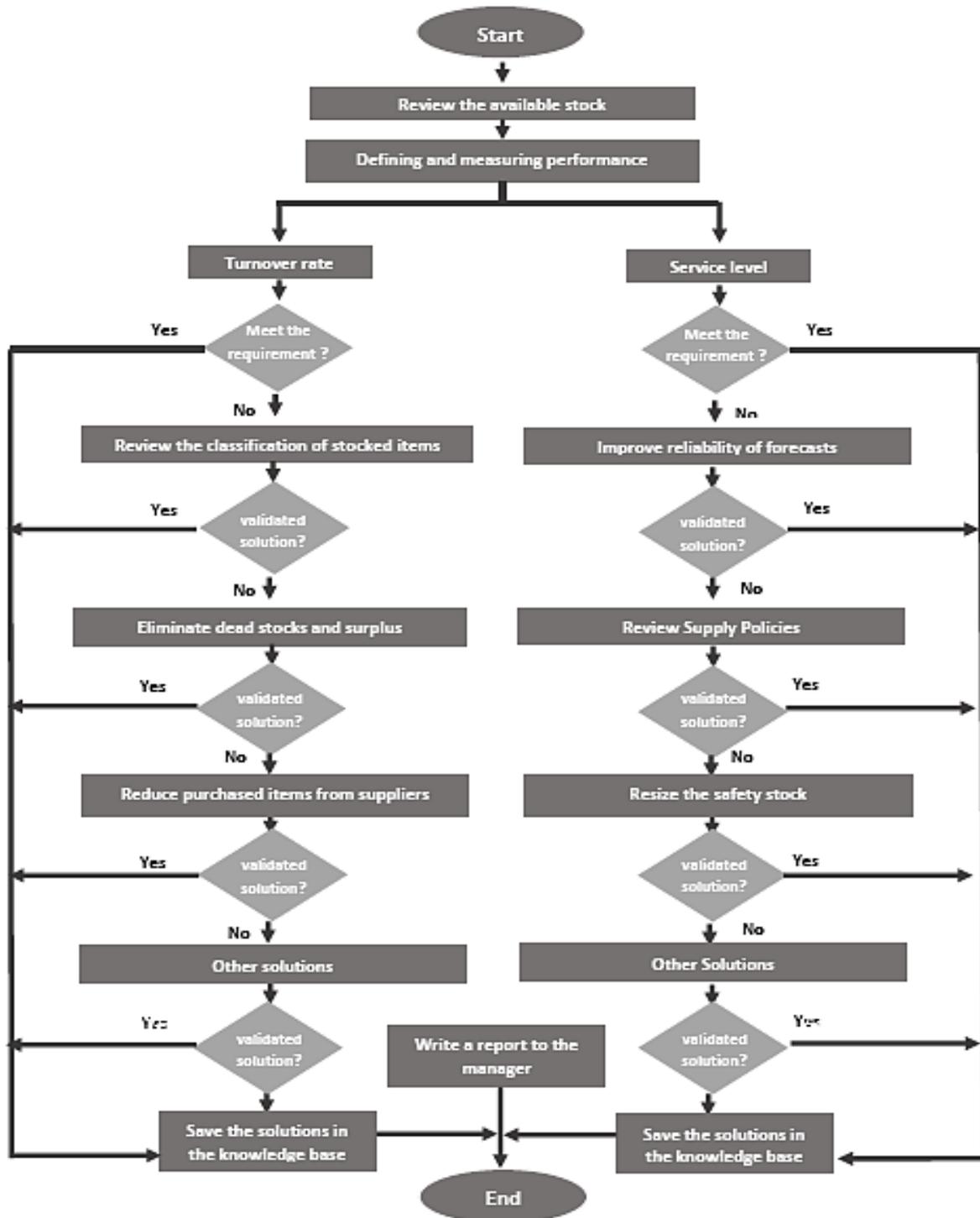
**Table 1:** Developed solution for KPI's improvement

Actions to be taken to improve the service level KPI	
<b>Improve reliability of forecasts [12]</b>	-Provide necessary resources for data verification that are used to calculate forecasts - Involve staff in charge of forecasts and make them responsible for the reliability of the latter
<b>Review Supply Policies [8]</b>	The revision of the parameters related to the stock management is a path of improvement that deserves to be explored: -The aim of this action is to allocate an adequate supply policy for each category of item. -It will also be necessary to determine the optimum order quantity according to the lowest storage cost and the average customer demand.
<b>Resize the safety stock [8]</b>	-The security stock is one of the major parameters of inventory management. -It is defined based on a given target service level.
Actions to be taken to improve the stock turnover KPI	
<b>Review the classification of stocked items [6]</b>	-It's about focusing on the most sold products with high consumption by applying the principle of 20: 80 law and only invest in items that provide maximum benefit. - The elimination of inventories with a lower turnover rate will improve the overall turnover of the entire company.
<b>Eliminate dead stocks and surplus</b>	-The great threat of supply strategies is the variation of demand. This is why companies maintain additional stocks of product to meet an unknown demand, which leads to overstocking. -Resources to a reliable forecasts should be used in this direction to avoid investing in safety stocks.

**Reduce quantities purchased from suppliers [15]**

- As part of the approach "0 stock" supply must meet demand.  
 -This means that instead of buying high quantities, it would be preferable to order economical batches by replenishing the stock only after the quantity of the product is sold.

These are some improvements that are part of a quick diagnosis and can be used without significant investments. However, other strategic solutions can be explored, such as increasing sales, by marketing strategies improvement and boost sales by focusing on advertising. As shown in figure 5, any operation will be recorded in the knowledge base.



**Figure 5:** Flowchart of solutions for each KPI

## CONCLUSION

This paper proposed a closed loop approach for inventory management using key performance indicators. The inventory turnover and service level are the KPI's that were used in this work. For decision-making, a procedure based on variety of solutions and alternatives has been established for each selected KPI's. The work in the near future will focus on the improvement of this approach and validation through a case study from the industrial environment.

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