The Role of Hybrid Make-to-Stock (MTS) – Make-to-Order (MTO) and Economic Order Quantity (EOQ) Inventory Control Models in Food and Beverage Processing Industry

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Abstract. The inventory model had been utilized since the early 1900s. The implementation of the inventory management model is generally to ensure that an organisation is able to fulfil customer's demand at the lowest possible cost to improve profitability. This paper focuses on reviewing previous published papers regarding inventory control model mainly in the food and beverage processing industry. The author discusses four inventory models, which are the make-to-stock (MTS), make-to-order (MTO), economic order quantity (EOQ), and hybrid of MTS-MTO models. The issues raised by the researchers on the above techniques as well as the elements need to be considered upon selection have been discussed in this paper. The main objective of the study is to highlight the important role played by these inventory control models in the food and beverage processing industry.

1. Introduction

Inventory control is the act of maintaining the inventory at a reasonable level that could fulfil customer's demand in terms of date and amount, which leads to minimising total costs and maximising profit [1]–[3]. A firm with an efficient inventory control improves its competitiveness [3], [4]. Inventory management control methods include Just In Time (JIT), Materials Requirement planning (MRP), Vendor Management Inventory (VMI), and Distribution Resource planning (DRP) [5]. In replenishing inventory, there are three types of order size models including the basic economic order quantity (EOQ), economic production quantity (EPQ), and quantity discount model [6].

According to Bushuev et al. inventory models are broadly classified as deterministic or stochastic. A deterministic model assumes that the demand and lead time of an inventory system is clearly known, which leads to a rather simple and direct mathematical modelling whereas stochastic model, which first appeared in the early 1950s considers the uncertainty and variability that exist in real-world situations. The mathematical structure for the stochastic model turns out to be more complex compared to the deterministic model due to the uncertainty [7]. Basically, an inventory model is classified as deterministic when the demand for a period is known while it is considered as stochastic when the demand is a random variable with a known probability distribution [8], [9]. A basic EOQ model lies under the deterministic model category [8].

2. Inventory Control Models In Food And Beverage Industry

Researchers claimed that the inventory management is very vital in a food and beverage processing industry as it involves the perishability of the items despites the main issue of cost [10]–[16][17][18]. In this section, several inventory control models used in the food and beverage industry are described briefly. The inventory models include the make-to-stock (MTS) policy, make-to-order (MTO) policy, economic order quantity (EOQ) model, and the hybrid of MTS-MTO inventory system.

2.1. Make-To-Stock (MTS) Policy

MTS is also known as Push System [10], [11], [19] among most researchers. In a MTS policy, products are made and stored as inventory based on forecasted demand [20]. Customers' demand is satisfied from the stock. Sangeetha et al. [10] in their paper adopted a continuous review method along with the MTS inventory model. Their target was to obtain the optimal set of production rate, which in return minimizes the total cost per unit time expected. A semi Markov decision method is used to formulate the problem and its application scope is quite wide. Noorwali [20] in his paper outlined several characteristics of MTS:

- Inventory level: High due to stocks of finished goods
- Cost : Production of large number of products results to an expensive production
- Production : Helps in increasing production utilization by running for long term
- Demand : Depends on forecasts
- Scheduling : Main key performance is *throughput*

2.2. Make-To-Order (MTO) Policy

Most researchers define the MTO policy as the Pull System [10], [11], [19]. MTO compared to MTS is more flexible to respond to the changes in demand. In a MTO policy, the production process begins only after the orders are received from the customers [20]. In some cases, the MTO policy begins right from the beginning of the production process. Meanwhile in some cases, some parts are assembled earlier and the process only continues when orders are received. Characteristics of the MTS policy is outlined by Noorwali [20] in his paper:

- Inventory level : Low due to orders being dispatched to customers after production
- Cost : Flexible system in production lines helps in the reduction of extra costs
- Production : The production schedule is more variable and flexible to production mix
- Demand : Based on customer's requirements
- Scheduling : Main key performance is *on time delivery rate*

2.3. Hybrid MTS-MTO Policy

A hybrid MTS-MTO policy combines both the MTS and MTO policy within the same organisation. The hybrid of MTO and MTS is quite common in the food and beverage processing industry. Soman, Van Donk, and Gaalman [11] for instance focused on a multi-product inventory control system practicing the combination of the MTO and MTS models. They listed several issues with respect to the MTO-MTS models in the food processing industry and had figured out a hierarchical planning framework in order to solve the issues. The framework mainly consists of three levels. The first level decides which product will be MTO or MTS. The second level specifies the target level for MTS products and sets the policies for MTO orders. At the third level, production orders are scheduled and sequenced. The policy is described in figure 1.

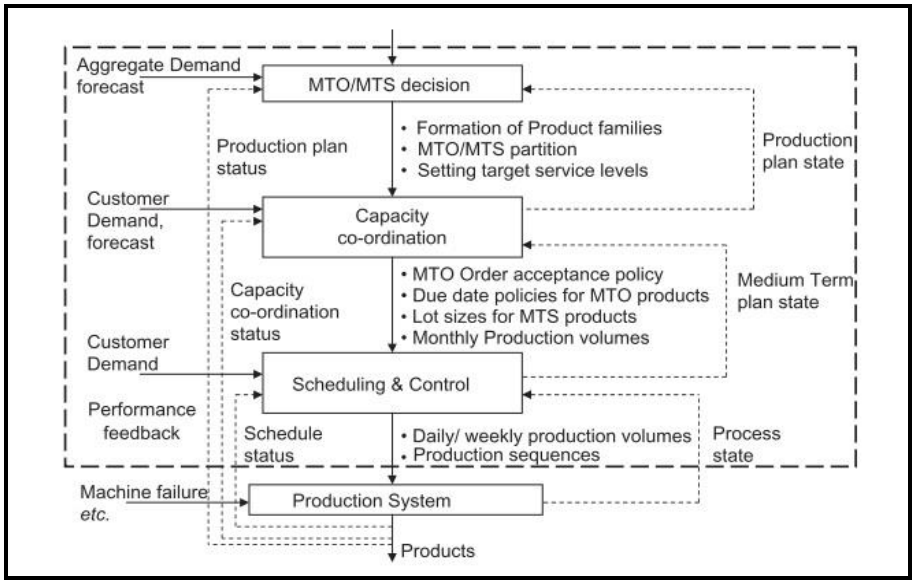

Figure 1. Hierarchical approach to MTO–MTS problem [11]

2.4. Economic Order Quantity (EOQ)

The most important decision in managing inventory is to find out how large the inventory replenishment order should be and when the order should be placed [1], [6], [7], [21]. The Harris economic order quantity (EOQ) model appeared decades ago aiding managers to determine the size and timing of inventory replenishment [22], [23][24]. The model appeared in the literature in various variants and extensions [7][25]. Bushuev et al. highlighted three research evolutions of this model up to the 1950s, which had formed the foundation of classical inventory models known as the economic production quantity (EPQ) model [26], the reorder point concept [27], and the stochastic EOQ [7]. Seyedi et al. in their research had combined the use of EOQ and EPQ [1]. According to Buxey, variations in usage rate as well as vendor performance are ignored in a basic EOQ, which results in the fixed-order quantity (Q-type) and fixed-order period (P-type) system [21].

2.4.1. Fixed-order Quantity (Q-type). In a Q-type system, the inventory is replenished when the inventory level reaches a certain level known as the reorder point, R [10], [21], [28]. The reorder point (ROP) is defined by Sani [28] as:

$$ROP = \text{Buffer or Safety Stock} + (\text{Usage} \times \text{Lead Time}) \quad (1)$$

In this system, the replenishment quantity, Q remains constant [21]. According to Buxey [21], a Q-type system is desirable for replenishing truckloads, getting quantity discount from vendors, purchasing expensive and critical items, purchasing items of lumpy and low demand, and also unfrequently ordered goods.

2.4.2. Fixed-order Period (P-type). For a P-type system, the inventory is replenished at a fixed interval known as T. The interval T is known as the Economic Order Period (EOP) and could be obtained through [21]:

$$EOP = EOQ/D \quad (2)$$

Where D is the forecasted annual demand of the item. In this case, the replenishment quantity, Q is the variable. Q is responsible to return the stock level to a target maximum level known as S [21]. Buxey [21] in his paper stated that a P-type system is desirable for ordering multiple items from the same

supplier, purchasing cheap and high in demand items, perishable items, goods that could be purchased seasonal, and items having a moderate to low usage value with stable demand.

2.5. Inventory Models vs Number of Research Papers

Figure 2 illustrates the number of research papers with respect to inventory models in the food and beverage industry. There are 61 papers altogether. Review of research papers from various sources leads to classical make-to-stock (MTS), classical make-to-order (MTO), Hybrid MTS-MTO, and economic order quantity (EOQ). Therefore, these four inventory models were chosen as the root of this review paper. The classical MTS [20], [29]–[37] and MTO [20], [30], [31], [33]–[35], [38]–[41] were mentioned in ten research papers respectively. The Hybrid MTS-MTO inventory model were discussed in 20 papers [11], [34], [39], [42]–[58]. The EOQ inventory model meanwhile was the most discussed model by authors [18], [59]–[79] as discussed in 21 research papers.

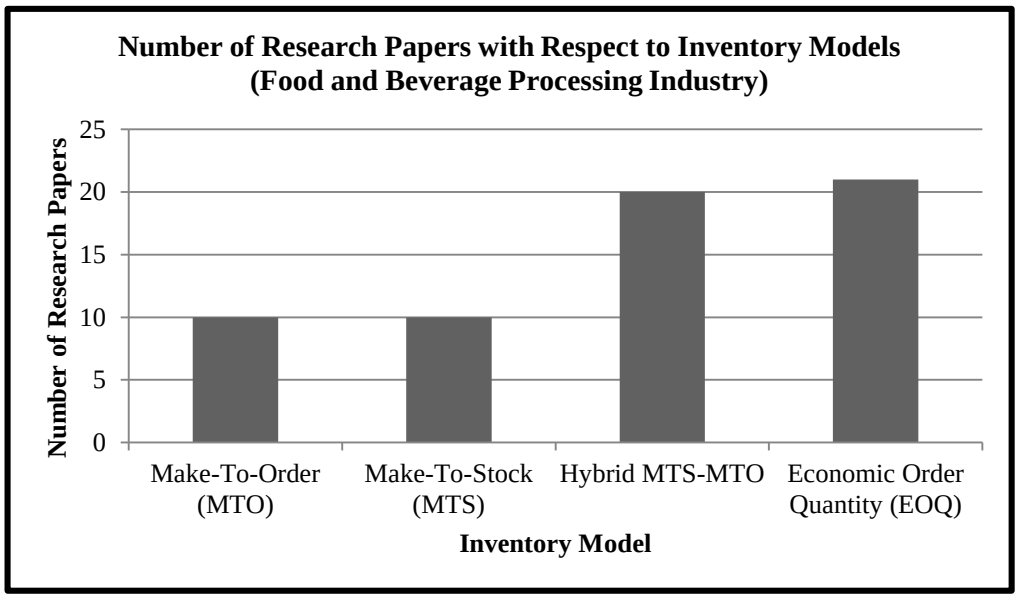

Figure 2. Number of research papers with respect to inventory models in the food and beverage processing industry

Based on the review, the classical MTS and MTO inventory models are less popular because they could only adapt to one demand condition. A pure MTS inventory model results in a high safety stock and it is not good for this industry as the items involve in the perishability nature. Meanwhile, a pure MTO is costly to setup in this type of industry [39]. Therefore, most researchers opt the implementation of Hybrid MTS-MTO inventory model as it is more flexible to react to customer demand despites being more economical. Most researchers also focus on the Hybrid MTS-MTO inventory model to tackle the demand of the customers. Upon implementing the Hybrid MTS-MTO inventory model, researchers [11], [34], [39], [42]–[58] agreed to highlight:

- Separating products into MTS or MTO
- Determining the lot sizes for the MTS and MTO
- Choosing between static or dynamic approach
  - Static approach : Separate set of machines/production line for MTS and MTO items
  - Dynamic approach : Using flexible machines that could switch between MTS and MTO

The EOQ inventory model meanwhile was often used in the papers as the raw material inventory replenishment model. The basic model, which is simple and straight-forward, seems easy to adapt to

various stocks conditions. The model could be developed into more complex models to adapt to different occasions including:

- A perishable inventory system with fixed lifetime and lead time [69]
- An EOQ model involving perishable products under special sale and shortage [70]
- An integrated production-inventory model [66][77]
- An inventory model considering deteriorating items with shortages and time-varying demand [74]
- An inventory model that deals with items ordered in batches [79]
- An inventory model with time and price dependent demand [62]

Both the Hybrid MTS-MTO and the EOQ model played a significant role in reducing the inventory level [42], [60], [63], [64], [66]. This eventually increase overall net profit by reducing the inventory related costs [42], [61], [69], [70], [77].

3. Issues Raised By Researchers

Upon implementing the MTS inventory model, there are several issues raised by the researchers in their papers. The issues are:

- Leading to a congested shop floor [80]
- Increasing in inventory level due to uncertainty of demand [19]

As for the MTO inventory model, some issues raised by the authors include:

- Production schedule unable to meet demand congestion [19]
- The need to have a good sourcing and supplier selection [38]

Hybrid MTS-MTO is one of the popular inventory models among researchers. Issues of implementing the inventory model are included in their papers, which some of them as follows:

- Unknown performance if compared to other techniques such as Kanban, CONWIP, MRP, POLCA, etc. [42]
- Determining the right decoupling point between MTS and MTO [43]
- Organisational and cultural barriers at the company [43]

Being the most discussed inventory model among researchers, the EOQ inventory model has its own issues raised by the authors. The issues include:

- Cost implications [64].
  - Production and storage facilities
  - Transportation/handling
  - Information/IT systems
  - Personnel

- Examining favourable/unfavourable conditions [64]
  - Demand related conditions
  - Product related conditions
  - Production related conditions

- Lack of proper knowledge and training of unskilled workers [60]

- Improper recording data method and labelling system at warehouse [60]
- Employees often leave the organisation [60]

4. Elements To Consider Before Selecting The Techniques

There are several elements that need to be considered before choosing between MTO and MTS as discussed by Altendorfer and Minner [80] in their paper. They assume that a decreasing setup time leads to an increase of MTO products compared to MTS products. They also state that products with higher demand rates are produced by MTS policy while products with lower demand rates are produced by MTO policy. However, MTO is used for both products with high and low demand rates when the customer-required lead time is constant. They include customer impatience as an element to be considered. Whenever customers are impatient, the firm needs to consider a MTS policy. In this case, the MTS policy includes advanced demand information while the MTO is modelled as a pure policy with a zero base stock level.

In a hybrid MTO-MTS policy, Soman,Van Donk, and Gaalman [11] described the similar considerations for traditional MTO or MTS. The only difference is that in hybrid policy, the organisation choses either MTO or MTS for its different products depending on the elements stated above. Studies listed three main characteristics to be considered in the case of food and beverage processing industry [11]:

- Plant characteristics
  - An extensive capacity of the shop floor with oriented flow design
  - An extensive cleaning times and sequence dependent setup time different among products

- Product characteristics
  - A variety of quality as well as supply for raw material
  - A limited shelf life for its raw material, semi-finished product, and finished product
  - Using either volume or weight as the unit of measure

- Production process characteristics
  - A variable yield and processing time for its processes
  - A divergent flow structure
  - Multiple recipes for a single product
  - Labour intensive at the packaging stage and not at the processing stage
  - The capacity determines the production rate.

Adeyemi and Salami [59] had outlined the assumptions needs to be considered upon calculating an EOQ. The assumptions are as follows:

- The stock holding cost is known and constant.
- The ordering cost is known and constant.
- The demand rate is known.
- The price per unit is known and constant.
- The replenishment is made instantaneously.
- Stock-outs are not allowed.

5. Conclusion

To date, not many opt the usage of the traditional MTO or MTS policy individually. The usage of MTS and MTO hybrid as a significant policy has been observed in the food processing industry due to the uncertain demand received by organisations as well as the food processing industry deals with perishable items. The EOQ inventory model is equivalently reliable in this industry. The basic EOQ

model that could be developed into various models to adapt the company's atmosphere is the reason why the model is used.

There are various issues involved upon implementing every single inventory model to an organisation. From the classical MTS, MTO, and EOQ to the more complicated Hybrid MTS-MTO and developed EOQ inventory model, the main concern upon implementing a model is the costs of implications as well as the organisational and cultural barriers. Other issues might be added to these two main issues depending on involved inventory models.

It is obvious that Hybrid MTS-MTO and EOQ play a significant role in the food and beverage industry. Most companies adopt these inventory control models as the best way to maintain the raw materials in an optimal level, which results in minimization of investment in an inventory. Besides, review from other papers indicates a positive relationship between inventory and sales as well as inventory and production cost. Although it does not denote that production costs or sales are determined by inventory, it could be a beneficial sign of the expected sales.

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