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 despite 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.
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:

\[
ROP = \text{Buffer or Safety Stock} + (\text{Usage} \times \text{Lead Time})
\]  

(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 infrequently 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]:

\[
EOP = \frac{EOQ}{D}
\]  

(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.

![Number of Research Papers with Respect to Inventory Models](image)

**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 despite 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 chooses 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
  o An extensive capacity of the shop floor with oriented flow design
  o An extensive cleaning times and sequence dependent setup time different among products

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

• Production process characteristics
  o A variable yield and processing time for its processes
  o A divergent flow structure
  o Multiple recipes for a single product
  o Labour intensive at the packaging stage and not at the processing stage
  o 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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References
[1] I Seyedi, S Mirrazadeh, A Maleki-Daronkolaei, M Mukhtar, and S Sahran 2016 An inventory model with reworking and setup time to consider effect of inflation and time value of money Journal of Engineering Science and Technology 11 3 pp. 416–430
[2] L Abuhilal 2006 Supply chain inventory control: A Comparison among JIT, MRP, and MRP with information sharing using simulation Engineering Management Journal 18 2
[3] V Chalotra 2013 Inventory management and small firms growth: An analytical study in supply chain Vision: The Journal of Business Perspective 17 3 pp. 213–222
[4] J Liu, X Liao, W Zhao, and N Yang 2016 A classification approach based on the outranking model for multiple criteria ABC analysis Omega 61 pp. 1–16
[5] D M Dinu 2013 Inventory management within a food factory Competitiveness of Agro-Food and Environmental Economy 5 pp. 269–275
[6] E N Roslin, S N Abdul Razak, M Z Bahrom, and M A Abd Rahman 2015 A conceptual model of inventory management system using an EOQ technique – A case study in automotive service industry Journal of Science & Engineering Technology 2 2
[7] M A Bushuev, A Guiffrida, M Y Jaber, and M Khan 2015 A review of inventory lot sizing review papers Management Research Review 38 3 pp. 283–298
[8] Chapter 19: Inventory Theory pp. 935–1008
[9] H E Scarf 2002 Chapter 25: Inventory Theory pp. 1–55
[10] N Sangeetha, B Sivakumar, and G Arivarignan 2015 Optimal control of production time of perishable inventory system with finite source of customers Opsearch 52 3 pp. 412–430
[11] C A Soman, D P Van Donk, and G Gaalman 2004 Combined make-to-order and make-to-stock in a food production system International Journal of Production Economics 90 2 pp. 223–235
[12] L M Chen and A Sapra 2013 Joint inventory and pricing decisions for perishable products with two-period lifetime Naval Research Logistics 60 pp. 343–366
[13] C C Liang 2013 Smart inventory management system of food-processing-and- distribution industry Procedia Computer Science 17 pp. 373–378
[14] W Intayoad and P Temdee 2013 Inventory cloud service for local SME: A scenario study for ice cream factory 13th International Symposium on Communications and Information Technologies: Communication and Information Technology for New Life Style Beyond the Cloud pp. 741–745
[15] C C Liang 2013 Inventory prediction in a food-processing-and-distribution company 5th
[16] G Fauza, Y Amer, S H Lee, and H Prasetyo 2015 An inventory model of production-inventory policy for food products considering quality loss in raw materials *Proceedings of the 2015 IEEE IEEM* pp. 910–914

[17] A Herbon, E Levner, and T C E Cheng 2014 Perishable inventory management with dynamic pricing using time–temperature indicators linked to automatic detecting devices *International Journal of Production Economics* 147 pp. 605–613

[18] A Bozorgi 2016 Multi-product inventory model for cold items with cost and emission consideration *International Journal of Production Economics* 176 pp. 123–142

[19] Y Günalay 2011 Efficient management of production-inventory system in a multi-item manufacturing facility: MTS vs. MTO *International Journal of Advanced Manufacturing Technology* 54 9–12 pp. 1179–1186

[20] A Noorwali 2014 Apply MTS-MTO & rule base in food flow processing system *International Journal of Scientific & Engineering Research* 5 1, pp. 2218–2225

[21] G Buxey 2006 Reconstructing inventory management theory *International Journal of Operations & Production Management* 26 9 pp. 996–1012

[22] F W Harris 1913 How many parts to make at once *Factory, The Magazine of Management* 10 2 pp. 135–136

[23] C K Sivashankari and S Panayappan 2014 Production inventory model for two-level production with deteriorative items and shortages *International Journal of Advanced Manufacturing Technology* 76 9–12 pp. 2003–2014

[24] J Rezaei 2014 Economic order quantity for growing items *Int. J. Production Economics* 155 pp. 109–113

[25] M Holmbom and A Segerstedt 2014 Economic order quantities in production: From Harris to economic lot scheduling problems *International Journal of Production Economics* 155 pp. 82–90

[26] R H Wilson 1934 A scientific routine for stock control *Harvard Business Review* pp. 116–129

[27] J K Arrow, T Harris, and J Marschak 1951 Optimal inventory policy *Econometrica* 19 3 pp. 250–272

[28] M H Sani 2014 Applicable inventory control models for agricultural business managers: Issues and concerns *Trends in Agricultural Economics* 7 1 pp. 11–25

[29] J L O Nieminen 2014 *Using Theory of Constraints to increase control in a complex manufacturing environment - Case Candy Co : Make-to-stock production with a broad product offering and hundreds of components* (Aalto University)

[30] X F Shao and M Dong 2012 Comparison of order-fulfilment performance in MTO and MTS systems with an inventory cost budget constraint *International Journal of Production Research* 50 7 pp. 1917–1931

[31] J Olhager and D I Prajogo 2012 The impact of manufacturing and supply chain improvement initiatives: A survey comparing make-to-order and make-to-stock firms *Omega* 40 2 pp. 159–165

[32] R Kaipia, I Dukovska-Popovska, and L Loikkanen 2013 Creating sustainable fresh food supply chains through waste reduction *International Journal of Physical Distribution & Logistics Management* 43 3 pp. 262–276

[33] H C Dreyer, J O Strandhagen, M K Thomassen, A Romsdal, and E Gran 2014 Supply chain control principles in local food production: A Norwegian case study *International Journal on Food System Dynamics* 5 2 pp. 53–68

[34] S Wilson 2013 Categorizing WIP inventories in the food industry *Journal of Agribusiness in Developing and Emerging Economies* 3 1 pp. 27–48

[35] F S Algassem 2016 Integration of lean six sigma with multi agent systems in the food distribution industry in small to medium enterprises (SMEs)

[36] M H Yokoyama, A L da Silva, and E L Piato 2014 Private label and manufacturing strategies: A
case study of Brazilian suppliers from the food industry 2 pp. 535–552

[37] B Sharda and N Akiya 2012 Selecting make-to-stock and postponement policies for different products in a chemical plant: A case study using discrete event simulation *International Journal of Production Economics* **136** 1 pp. 161–171.

[38] H Li and K Womer 2012 Optimizing the supply chain configuration for make-to-order manufacturing *European Journal of Operational Research* **221** 1 pp. 118–128.

[39] P Amorim, C H Antunes, and B Almada-Lobo 2011 Multi-objective integrated lot-sizing and scheduling with vehicle routing problem dealing with perishability issues *Industrial & Engineering Chemistry Research* **50** pp. 3371–3381.

[40] E Jensen 2014 Measuring cost effectiveness of product wheels in food manufacturing

[41] J W M Bertrand and H P G Van Ooijen 2012 The capacity investment decision for make-to-order production systems with demand rate control *International Journal of Production Economics* **137** 2 pp. 272–283.

[42] D Claudia, J Zhang, and Y Zhang 2007 A hybrid inventory control system approach applied to the food industry *Proceedings of the 2007 Winter Simulation Conference* pp. 1699–1707.

[43] D P Van Donk 2001 Make to stock or make to order: The decoupling point in the food processing industries *International Journal of Production Economics* **69** 3 pp. 297–306.

[44] I J Jeong 2011 A dynamic model for the optimization of decoupling point and production planning in a supply chain *International Journal of Production Economics* **131** 2 pp. 561–567.

[45] P Hedenstierna and A H C Ng 2011 Dynamic implications of customer order decoupling point positioning *Journal of Manufacturing Technology Management* **22** 8 pp. 1032–1042.

[46] J Olhager The role of decoupling points in value chain management

[47] A Noorwali Apply MTS-MTO and principle component in food flow processing

[48] J Köber and G Heinecke 2012 Hybrid production strategy between make-to-order and make-to-stock - A case study at a manufacturer of agricultural machinery with volatile and seasonal demand *Procedia CIRP* **3** 1 pp. 453–458.

[49] N O Fernandes, M Gomes, and S Carmo-Silva 2013 Workload control and order release in combined MTO-MTS production *The Romanian Review Precision Mechanics, Optics and Mechatronics* **43** pp. 33–39.

[50] A Romsdal, E Arica, J O Strandhagen, and H C Dreyer 2013 Tactical and operational issues in a hybrid MTO-MTS production environment: The case of food production *IFIP Advances in Information and Communication Technology* **398** 2 pp. 614–621.

[51] A Romsdal 2014 *Differentiated production planning and control in food supply chain* (Norwegian University of Science and Technology)

[52] H-O Günther 2014 The block planning approach for continuous time-based dynamic lot sizing and scheduling *Business Review* **7** 1 pp. 51–76.

[53] B Beemsterboer, M Land, and R Teunter 2015 Hybrid MTO-MTS production planning: An explorative study *European Journal of Operational Research* **248** 2 pp. 453–461.

[54] C A Soman, D P van Donk, and G J C Gaalman 2007 Capacitated planning and scheduling for combined make-to-order and make-to-stock production in the food industry: An illustrative case study *International Journal of Production Economics* **108** 1–2 pp. 191–199.

[55] H Raffiei and M Rabbani 2012 Capacity coordination in hybrid make-to-stock/make-to-order production environments *International Journal of Production Research* **50** pp. 773–789.

[56] Z G Zhang, I Kim, M Springer, G Cai, and Y Yu 2013 Dynamic pooling of make-to-stock and make-to-order operations *International Journal of Production Economics* **144** 1 pp. 44–56.

[57] M Khakdaman, K Y Wong, B Zohoori, M K Tiwari, and R Merkert 2014 Tactical production planning in a hybrid make-to-stock–make-to-order environment under supply, process and demand uncertainties: A robust optimisation model *International Journal of Production Research* **53** 5 pp. 1358–1386.

[58] T Immawan, Marimin, Y Arkeman, and A Maulana 2015 Sustainable supply chain management
for make to stock-make to order production typology case study : Batik industry in Solo Indonesia. European Journal of Business and Management 7 11 pp. 94–106

[59] S Adeyemi and A Salami 2010 Inventory management: A tool of optimising resources in a manufacturing industry: A case study of Coca-Cola bottling company, Ilorin plant. Journal Of Social Sciences 23 2 pp. 135–142

[60] M Sekar and R Geetha 2013 A study on inventory management with special reference to Suraj Foods, Kaniyampuram. Asia Pacific Journal of Management & Entrepreneur Research (APJMER) 2 4 pp. 103–112

[61] A Nugraha, A Rifin, and Sukardi 2016 Efficiency of raw material inventories in improving supply chain performance of CV. Fiva Food. Indonesian Journal of Business and Entrepreneurship 1 1 pp. 23–32

[62] A Mukhopadhyay and A Goswami 2014 Deteriorating inventory model with variable holding cost and price dependent time varying demand. 2nd International Conference on Business and Information Management (ICBIM) pp. 14–19

[63] N S Shobha and K N Subramanya 2012 Application of value stream mapping tools for process improvement a case study in a food manufacturing industry - A case study. International Conference on Challenges and Opportunities in Mechanical Engineering, Industrial Engineering and Management Studies pp. 11–13.

[64] H Wong, A Potter, and M Naim 2011 Evaluation of postponement in the soluble coffee supply chain: A case study. International Journal of Production Economics 131 1 pp. 355–364

[65] X Wang, D Li, and C O’Brien 2009 Optimisation of traceability and operations planning: An integrated model for perishable food production. International Journal of Production Research 47 11 pp. 2865–2886

[66] S K Goyal and A Gunasekaran 1995 An integrated production-inventory-marketing model for deteriorating items. Computers and Industrial Engineering 28 4 pp. 755–762

[67] P Amorim, H Meyr, C Almeder, and B Almada-Lobo 2013 Managing perishability in production-distribution planning: A discussion and review. Flexible Services and Manufacturing Journal 25 3 pp. 389–413

[68] J Wu, F B Al-Khateeb, J T Teng, and L E Cárdenas-Barrón 2016 Inventory models for deteriorating items with maximum lifetime under downstream partial trade credits to credit-risk customers by discounted cash-flow analysis. International Journal of Production Economics 171 pp. 105–115

[69] C Kouki, Z Jema, and S Minner 2015 A lost sales (r, Q) inventory control model for perishables with fixed lifetime and lead time. International Journal of Production Economics 168 pp. 143–157

[70] A A Taleizadeh, B Mohammadi, L E Cárdenas-Barrón, and H Samimi 2013 An EOQ model for perishable product with special sale and shortage. International Journal of Production Economics 145 1 pp. 318–338

[71] R Hlioui, A Gharbi, and A Hajji 2015 Replenishment, production and quality control strategies in three-stage supply chain. International Journal of Production Economics 166 pp. 90–102

[72] J Wu and Y L Chan 2014 Lot-sizing policies for deteriorating items with expiration dates and partial trade credit to credit-risk customers. International Journal of Production Economics 155 pp. 292–301

[73] A Andriolo, D Battini, R W Grubbström, A Persona, and F Sgarbossa 2014 A century of evolution from Harris’s basic lot size model: Survey and research agenda. International Journal of Production Economics 155 pp. 16–38

[74] J Sicilia, M González-De-La-Rosa, J Febles-Acosta, and D Alcaide-López-De-Pablo 2014 An inventory model for deteriorating items with shortages and time-varying demand. International Journal of Production Economics 155 pp. 155–162

[75] Y Qin, J Wang, and C Wei 2014 Joint pricing and inventory control for fresh produce and foods with quality and physical quantity deteriorating simultaneously. International Journal of
Production Economics 152 pp. 42–48
[76] S C Chen, J T Teng, and K Skouri 2014 Economic production quantity models for deteriorating items with up-stream full trade credit and down-stream partial trade credit International Journal of Production Economics 155 pp. 302–309
[77] G A Emamverdi, M S Karini, and M Shafiee 2011 Application of optimal control theory to adjust the production rate of deteriorating inventory system (Case study: Dineh Iran Co.) Middle-East Journal of Scientific Research 10 4 pp. 526–531
[78] P Velarde, J M Maestre, I Jurado, I Fern, B I Tejera, and J R Prado 2014 Application of robust model predictive control to inventory management in hospitalary pharmacy IEEE Emerging Technology and Factory Automation pp. 5901–5906
[79] O Baron, O Berman, and D Perry 2010 Continuous review inventory models for perishable items ordered in batches Mathematical Methods of Operations Research 72 2 pp. 217–247
[80] K Altendorfer and S Minner 2014 A comparison of make-to-stock and make-to-order in multi-product manufacturing systems with variable due dates IIE Transactions 46 3 pp. 197–212