OPTIMIZING AN INVENTORY MODEL FOR PERISHABLE PRODUCTS WITH PRODUCT RELIABILITY AND TIME DEPENDENT DEMAND USING PENTAGONAL-FUZZY NUMBER

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Abstract

Enhancing inventory control for perishable goods is challenging since their shelf life is short and their demand is constantly changing. The current research examines into a more advanced inventory model for perishable goods, where demand is affected by both time and the reliability the product. The model occupies a pentagonal-fuzzy environment to assist with inherent uncertainties with these kinds of systems. This gives a more accurate picture of how demand fluctuates over time. Using analytical optimization techniques, the model targets to minimize total inventory costs, consisting of ordering cost, holding cost, and deterioration cost while maintaining high service levels. The total cost function is defuzzified using the Graded Mean Integration Representation (GMIR) method. The study's results, which were verified by numerical evaluations, demonstrate that the model is better at cost reduction and boosting dependability than other models using the MATLAB software. This research contributes a robust framework for handling perishable inventory with uncertain situations, which has a major impact on optimizing the supply chain.

Keywords: Inventory Model, Perishable Products, Time and Reliability-Dependent Demand, Pentagonal-Fuzzy Environment, GMIR Method.

1. Introduction and Literature Review

Managing perishable inventory is a vital part of supply chain operations, especially when factoring in product reliability and time-dependent demand. Perishable items inherently have limited lifespans and experience quality deterioration over time, making their inventory management more complex than that of non-perishable goods. Beyond these challenges, the integration of fuzzy logic, particularly within a pentagonal-fuzzy framework, introduces additional complexity to more effectively address the uncertainties present in real-world situations.

Product reliability and demand variability are crucial in shaping effective inventory management strategies for perishable items. The demand for these products frequently changes over time due to factors like seasonality, market trends, and consumer preferences. Additionally, product reliability, which reflects the stability of product quality and lifespan, directly affects inventory decisions by influencing replenishment cycles and stock levels. The work by Yadav, Yadav, and Bansal [25] addresses deteriorating products that deteriorate simultaneously during storage by incorporating a two-warehouse system into an optimal inventory model to increase management efficiency. Their study extends earlier models by incorporating deterioration dynamics inside a multi-warehouse architecture, which lowers total costs and improves inventory control.

Many studies have examined inventory management for perishable goods, emphasizing the importance of including demand variability and product reliability in inventory models. Nahmias [7] offered an extensive review of perishable inventory models, detailing their features and the mathematical methods used for their management. Subsequent research has expanded on this groundwork, incorporating advanced mathematical techniques and computational tools to address the complexities of managing perishable inventory systems (Bakari et al., [1]). The influence of product reliability on inventory management has been thoroughly examined. Li and Liu [6] investigated how product reliability affects the formulation of optimal inventory policies, noting that increased reliability can reduce waste and lower costs. Additionally, other researchers have underscored the significance of integrating product reliability into perishable inventory models (Goyal & Giri, [5]]). Variations in demand over time are a key factor in inventory management. Various studies have developed models to address time-dependent demand, recognizing that demand for perishable products frequently exhibits specific patterns (Wee, [9]). Bhunia and Maiti [2] incorporated time-dependent demand into their inventory model for deteriorating items, showing how this approach can enhance inventory management. Yadav, A. S., Kumar, A., Yadav, K. K., & Rathee, S. [21], Kumar, K. [20], Mahata, S., & Debnath, B. K. [23], Mahata, S., & Debnath, B. K. [24], Yadav, K. K., Yadav, A. S., & Bansal, S. [22], the researchers, have carried out some recent research that examines deterioration's consequences and highlights the need for degradation measures in order to maximize inventory management.

The application of fuzzy logic in inventory management has become increasingly popular for handling uncertainty and ambiguity in demand and supply conditions. Zadeh [10] introduced fuzzy sets, which have since been utilized in many areas, including inventory management. Researchers have created fuzzy inventory models to better address the uncertainties present in real-world scenarios (Choudhury et al., [3]). Specifically, the pentagonal-fuzzy environment has been demonstrated to improve the flexibility and precision of inventory models for perishable products (Singh & Saxena, [8]). Recent research has concentrated on combining product reliability, time-dependent demand, and fuzzy logic into comprehensive inventory models. Giri et al. [4] created an integrated inventory model that accounts for product deterioration, time-varying demand, and fuzzy parameters. Poswal et al. [26] investigate a fuzzy EOQ model that accounts for price sensitivity and stock dependence while accounting for shortages. Through the use of fuzzy logic, their study enhances EOQ models by more effectively addressing the uncertainty associated with inventory and demand management. Their results suggest that these integrated approaches can greatly enhance inventory management outcomes for perishable products.

The literature highlights an increasing awareness of the significance of product reliability and time-dependent demand in managing perishable inventories. The use of fuzzy logic, especially within a pentagonal-fuzzy framework, presents a promising method for addressing the uncertainties inherent in these systems. This study seeks to advance this knowledge by creating and evaluating an inventory model for perishable products that incorporates these essential factors within a pentagonal-fuzzy context. Adak and Mahapatra [11], Mahapatra, G. S., Adak, S., & Kaladhar, K. [12], Manna, A. K., Dey, J. K., & Mondal, S. K. [13], Adak, S., & Mahapatra, G. S. [14], Rajput, N., Chauhan, A., & Pandey, R. K. [17], Adak, S., & Mahapatra, G. S. [15], Adak, S., & Mahapatra, G. S. [16], Khara, B., Dey, J. K., & Mondal, S. K. [18] and Mahapatra, G. S., Adak, S., Mandal, T. K., & Pal, S. [19] examine how reliability affects inventory systems, highlighting the need for reliability assessments to optimize inventory management.

2. Identified Research Gaps and Our Contributions

Despite extensive research, significant gaps persist in understanding perishable inventory management. Existing models often inadequately integrate product reliability within fuzzy environments and fail to fully address its impact on inventory strategies. Additionally, many models fall short by not effectively combining time-dependent demand with factors such as product deterioration and reliability. The application of pentagonal-fuzzy logic remains underexplored, and the defuzzification process using the Graded Mean Integration Representation (GMIR) method is not yet well understood.

Our study addresses these gaps by incorporating product reliability into an inventory model within a pentagonal-fuzzy framework, enhancing our understanding of its impact on inventory management. We also develop a model that effectively integrates reliability, product deterioration, and time-dependent demand. Moreover, we utilize the GMIR method for defuzzification and expand the application of pentagonal-fuzzy logic to better manage uncertainties, offering a more precise approach to handling fuzzy data in perishable inventory models.

3. Notations and assumptions

3.1. Notations

The mathematical model was formulated based on the following notations.

Table 1: *Notations*

Notation	Units	Description
x	Constant	Coefficient of demand function
y	Constant	Coefficient of demand function
Z	Constant	Coefficient of deterioration rate.
C_1	\$/unit	Shortage cost.
r	–	product reliability.
A	\$/unit	The ordering cost
$I_1(t)$	Units	Inventory (Stock) level at a time t.
$I_2(t)$	Units	Stock out Inventory (Stock) level at a time t.
C_3	\$/Units	Deterioration cost.
C_4	\$/Units	Holding cost.
Q	Units	The number of orders placed in each cycle.
$ATC(t_1, T)$	\$/Units	The function for average total inventory cost.

Table 2: *Decision-making parameters*

Notation	Units	Description
t_1	–	Time, where shortage is start.
T	Years	Cycle length.

3.2. Assumptions

The mathematical model was formulated based on the following assumptions.

1. The demand rate function is influenced by both time and product reliability, represented by $D(r,t) = xtr^y$, where $x, y > 0$ are constants.
2. Shortages are fully deferred.
3. The filling rate is unlimited, and there is no lead time.
4. The inventory system operates over an infinite time horizon.
5. The deterioration rate remains constant and is denoted by Z; $Z > 0$.

4. Crisp Inventory Model Formulation

Initially, Q units of perishable goods were ordered. During the time interval $t \in [0, t_1]$, the combined effects of deterioration and demand lead to a reduction in the inventory level until it falls to zero. Hence, shortages are permitted to happen within the time interval $t \in [t_1, T]$. The demand that arises during the shortage period $t \in [t_1, T]$ is entirely deferred. (See Figure 1).

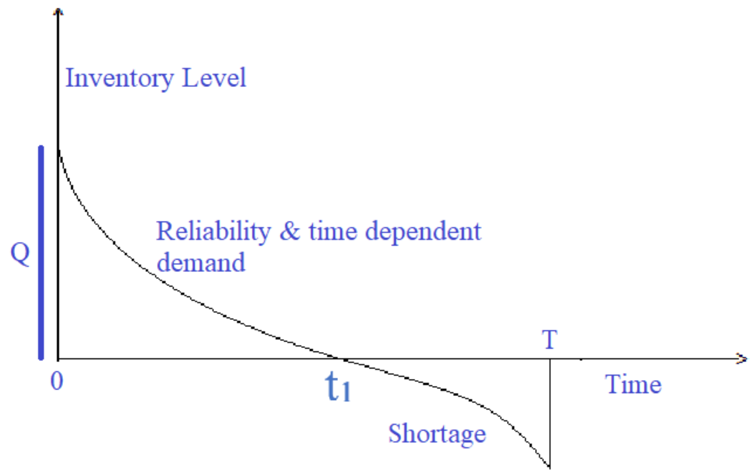

Figure 1: *A visual representation of the inventory system featuring fully backlogging.*

The stock level at $t = 0$ to $t = T$ is characterised in the differential equations as follows:

$$\frac{dI_1(t)}{dt} + ZI_1(t) = -(xtr^y); \quad t \in [0, t_1] \tag{1}$$

with the boundary conditions (B.C.) $I_1(t_1) = 0$ and $I_1(0) = Q$.

$$\frac{dI_2(t)}{dt} = -(xtr^y); \quad t \in [t_1, T] \tag{2}$$

with the boundary conditions (B.C.) $I_2(t_1) = 0$.

The equations (3) and (4) are the solutions of equations (1) and (2), respectively.

$$I_1(t) = \frac{xr^y}{Z^2}\left[1 - e^{Z(t_1-t)(1-Zt_1)}\right] - \frac{xr^y t}{Z} \tag{3}$$

$$I_2(t) = \frac{xr^y}{2}(t_1^2 - t^2) \tag{4}$$

Using the condition $I_1(0) = Q$ in (3), we get (4)

$$Q = \frac{xr^y}{Z^2}\left[1 - e^{Zt_1(1-Zt_1)}\right] \tag{5}$$

The overall cost per cycle comprises the following components:

1. **Opportunity cost:**

$$OC = A \tag{6}$$

2. **Deterioration cost:**

$$DC = ZC_3\left[Q - \int_0^{t_1}(xtr^y)dt\right] = \frac{ZC_3xr^y}{Z^2}\left[1 - e^{Zt_1(1-Zt_1)}\right] - \frac{ZC_3xr^yt_1^2}{2} \tag{7}$$

3. **Holding cost per cycle:**

$$HC = C_4\left[\int_0^{t_1} I_1(t)dt\right] = -\frac{C_4xr^y}{2Z^3}(2e^{Zt_1} + Z^2t_1^2 - 2Zt_1e^{Zt_1} - 2) \tag{8}$$

4. **Shortage cost:**

$$SC = C_1\int_{t_1}^{T} I_2(t)dt = -C_2xr^y\left[\frac{(T-t_1)^2(T+2t_1)}{6}\right] \tag{9}$$

Consequently, the retailer's total relevant inventory costs can be stated as follows:

$$ATC(t_1, T) = \frac{1}{T}[OC + DC + HC + SC]$$

$$ATC(t_1, T) = A + \frac{ZC_3xr^y}{Z^2}\left[1 - e^{Zt_1(1-Zt_1)}\right] - \frac{ZC_3xr^yt_1^2}{2} - \frac{C_4xr^y}{2Z^3}(2e^{Zt_1} + Z^2t_1^2 - 2Zt_1e^{Zt_1} - 2) - C_2xr^y\left[\frac{(T-t_1)^2(T+2t_1)}{6}\right] \tag{10}$$

5. Optimal Solution Approach for Crisp Model

The previously mentioned problem in equation [10] is highly nonlinear. We addressed these problems using an algorithm (described below) with the help of MATLAB software to find an optimal solution to the non linearity. To minimize total inventory cost function per unit time $ATC(t_1, T)$ the optimal values of t_1 and T can be obtained by solving the following equations:

$$\frac{\partial TC(t_1, T)}{\partial t_1} = 0 \;\; and \;\; \frac{\partial TC(t_1, T)}{\partial T} = 0$$

Further, for the total inventory cost function per unit time $ATC(t_1, T)$ to be convex, the following conditions must be satisfied

$$\frac{\partial^2 TC(t_1, T)}{\partial t_1^2} > 0, \; \frac{\partial^2 TC(t_1, T)}{\partial T^2} > 0, \;\; and \;\; \left(\frac{\partial^2 TC(t_1, T)}{\partial t_1^2} \cdot \frac{\partial^2 TC(t_1, T)}{\partial T^2} - \frac{\partial^2 TC(t_1, T)}{\partial t_1 \partial T}\right).$$

Algorithm:

Step I: Enter the values for all system parameters.
Step II: Construct the functions $ATC(t_1, T)$ as defined by equation [10].
Step III: Calculate the optimal values of the decision variables t_1^* and T^* using the previously mentioned optimal conditions
Step IV: Optimize the objective function $ATC^*(t_1, T)$ by employing the values t_1^* and T^*.
Step V: Determine the optimal values for $ATC^*(t_1, T)$.
Step VI: Finish.

6. Fuzzy Inventory Model Formulation

Given the environmental uncertainty, accurately defining all parameters is difficult. Therefore, we assume that parameters $\widetilde{x}, \widetilde{y}, \widetilde{Z}, \widetilde{C_1}, \widetilde{C_3}$ and $\widetilde{C_4}$ may vary within specific limits. Let pentagonal fuzzy numbers.

$$\widetilde{x} = (x_1, x_2, x_3, x_4, x_5), \quad \widetilde{y} = (y_1, y_2, y_3, y_4, y_5),$$
$$\widetilde{Z} = (Z_1, Z_2, Z_3, Z_4, Z_5), \quad \widetilde{C_1} = (C_{11}, C_{12}, C_{13}, C_{14}, C_{15}),$$
$$\widetilde{C_3} = (C_{31}, C_{32}, C_{33}, C_{34}, C_{35}), \quad \widetilde{C_4} = (C_{41}, C_{42}, C_{43}, C_{44}, C_{45}).$$

Total inventory cost function per unit time in fuzzy sense is given by:

$$\widetilde{ATC}(t_1, T) = A + \frac{\widetilde{Z}\widetilde{C_3}\widetilde{x}r^{\widetilde{y}}}{\widetilde{Z}^2}\left[1 - e^{\widetilde{Z}t_1(1-\widetilde{Z}t_1)}\right] - \frac{\widetilde{Z}\widetilde{C_3}\widetilde{x}r^{\widetilde{y}}t_1^2}{2} - \frac{\widetilde{C_4}\widetilde{x}r^{\widetilde{y}}}{2\widetilde{Z}^3}(2e^{\widetilde{Z}t_1} + \widetilde{Z}^2t_1^2 - 2\widetilde{Z}t_1e^{\widetilde{Z}t_1} - 2) - \widetilde{C_2}\widetilde{x}r^{\widetilde{y}}\left[\frac{(T-t_1)^2(T+2t_1)}{6}\right] \quad (11)$$

We convert the fuzzy Total Inventory Cost function per unit time, $\widetilde{ATC}(t_1, T)$, into a crisp value using the Graded Mean Integration Representation (GMIR) method. The Total Inventory Cost function is expressed as follows:

$$\widetilde{ATC}_{dgm}(t_1, T) = \frac{1}{12}\Big[\widetilde{ATC}_{dgm1}(t_1, T) + \widetilde{ATC}_{dgm2}(t_1, T) + \widetilde{ATC}_{dgm3}(t_1, T) + \widetilde{ATC}_{dgm4}(t_1, T) + \widetilde{ATC}_{dgm5}(t_1, T)\Big] \quad (12)$$

Where,

$$\widetilde{ATC}_{dgmi}(t_1, T) = A + \frac{\widetilde{Z}_i\widetilde{C_3}_i\widetilde{x}_ir^{\widetilde{y}_i}}{\widetilde{Z}_i^{\,2}}\left[1 - e^{\widetilde{Z}_it_1(1-\widetilde{Z}_it_1)}\right] - \frac{\widetilde{Z}_i\widetilde{C_{3i}}\widetilde{x}_ir^{\widetilde{y}_i}t_1^2}{2} - \frac{\widetilde{C_{4i}}\widetilde{x}_ir^{\widetilde{y}_i}}{2\widetilde{Z}_i^{\,3}}(2e^{\widetilde{Z}_it_1} + \widetilde{Z}_i^{\,2}t_1^2 - 2\widetilde{Z}_it_1e^{\widetilde{Z}_it_1} - 2) - \widetilde{C_{2i}}\widetilde{x}_ir^{\widetilde{y}_i}\left[\frac{(T-t_1)^2(T+2t_1)}{6}\right] \quad (13)$$

7. Optimal Solution Approach for Fuzzy Model

The previously mentioned problem in equation [12] is highly nonlinear. We addressed these problems using an algorithm (described below) with the help of MATLAB software to find an optimal solution to the non linearity. To minimize total inventory cost function per unit time $ATC(t_1, T)$ the optimal values of t_1 and T can be obtained by solving the following equations:

$$\frac{\partial TC(t_1, T)}{\partial t_1} = 0 \ \ and \ \ \frac{\partial TC(t_1, T)}{\partial T} = 0$$

Further, for the total inventory cost function per unit time $ATC(t_1, T)$ to be convex, the following conditions must be satisfied

$$\frac{\partial^2 TC(t_1, T)}{\partial t_1^2} > 0, \ \frac{\partial^2 TC(t_1, T)}{\partial T^2} > 0, \ \ and \ \left(\frac{\partial^2 TC(t_1, T)}{\partial t_1^2} \cdot \frac{\partial^2 TC(t_1, T)}{\partial T^2} - \frac{\partial^2 TC(t_1, T)}{\partial t_1 \partial T}\right).$$

Algorithm:

Step I: Enter the values for all system parameters.
Step II: Construct the functions $\widetilde{ATC}_{dgm}(t_1, T)$ as defined by equation [12].
Step III: Calculate the optimal values of the decision variables t_1^* and T^* using the previously mentioned optimal conditions

Step IV: Optimize the objective function $\widetilde{ATC}_{dgm}(t_1, T)$ by employing the values t_1^* and T^*.
Step V: Determine the optimal values for $\widetilde{ATC}_{dgm}(t_1, T)$.
Step VI: Finish.

8. Numerical Illustration

This section presents a numerical example to illustrate the proposed model for both crisp and fuzzy. To evaluate the best ordering strategies, we examine a retailer of perishable goods. The following examples are used to demonstrate the solution process:

8.1. Example

A numerical example is presented in this section to demonstrate the operation of the model. The input parameters used are as follows:

$$x = 0.015,\ y = 0.08,\ Z = 0.48,\ Q = 1674\ Units,\ A = 1320,\ r = 0.087,$$

$$C_1 = 3.1\ \$/unit,\ C_3 = 4.6\ \$/unit,\ C_4 = 0.08\ \$/unit.$$

The optimal solution obtained is as below:

$$t_1^* = 1.2\ Years,\ T^* = 1.6\ Years,\ ATC^* = \$807.4152/cycle.$$

9. Sensitivity analysis

This section utilizes sensitivity analysis to explore how changes in parameter values impact the optimal values. For these studies, each parameter was individually adjusted by ±5% A and ±10% B while keeping the other parameters at their original values. The results of the sensitivity analysis are shown in Table 3.

Table 3: *Effects of changing parameters of various kinds on the total cost and optimal solution.*

Parameters	% Change	% change in optimal value t_1^*	T^*	TC^*
x	-10%	1.1397	1.5216	802.3642
	-5%	1.1525	1.5107	803.9865
	+5%	1.1680	1.5072	808.0856
	+10%	1.1894	1.4941	811.2044
y	-10%	1.2057	1.5762	809.9627
	-5%	1.2584	1.5900	804.8506
	+5%	1.2714	1.6292	799.5823
	+10%	1.3043	1.6536	796.3281
Z	-10%	1.2839	1.6867	803.9647
	-5%	1.2185	1.6228	807.2578
	+5%	1.1835	1.5835	811.6492
	+10%	1.1318	1.5437	816.0247
r	-10%	1.2434	1.5721	810.0624
	-5%	1.2862	1.5937	806.1987
	+5%	1.3048	1.6213	798.1573
	+10%	1.3481	1.6591	792.1557
A	-10%	1.1913	1.6027	804.2684
	-5%	1.2046	1.6348	805.1678
	+5%	1.2761	1.6724	807.1775
	+10%	1.2934	1.6914	813.1576

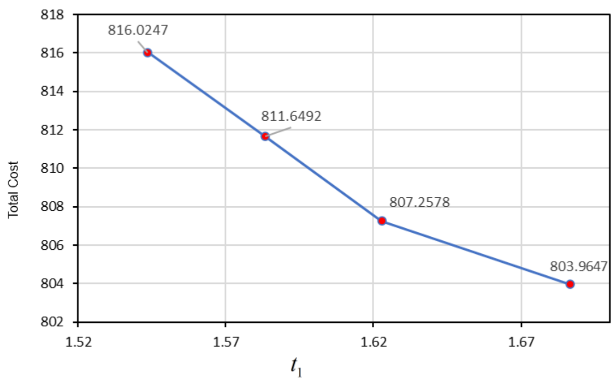

Figure 2: *Variation between $ATC(r, T)$ and t_1*

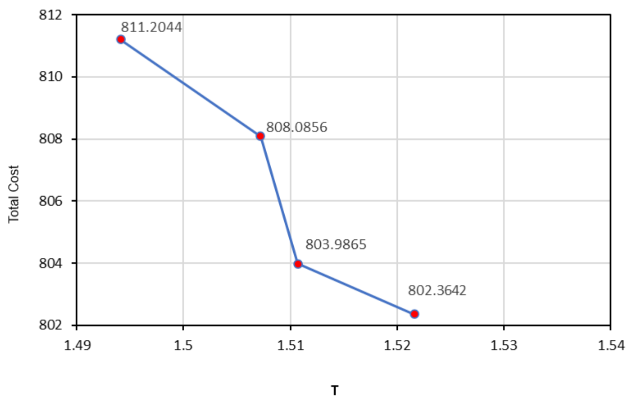

Figure 3: *Variation between $ATC(r, T)$ and T*

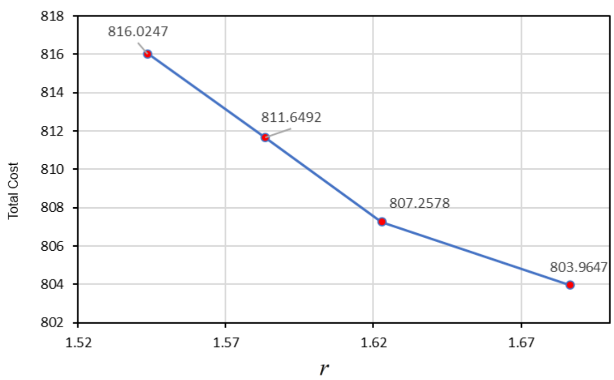

Figure 4: *Variation between $ATC(r, T)$ and reliability of the product (r)*

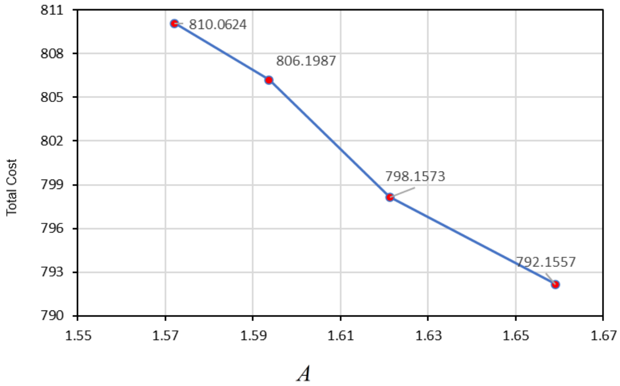

Figure 5: *Variation between $ATC(r, T)$ and Ordering cost (A)*

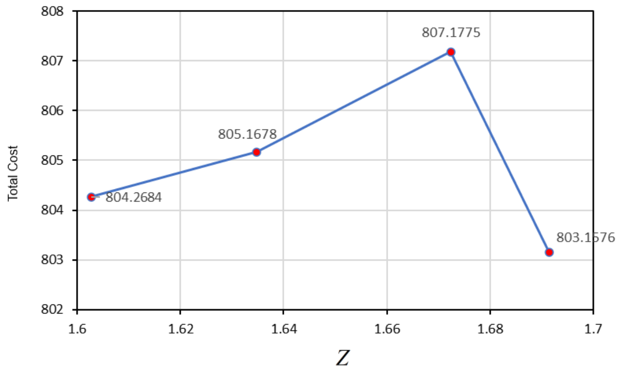

Figure 6: *Variation between $ATC(r, T)$ and deterioration rate Z*

10. Conclusion and Future Directions

This study examined the impact of product reliability and time-dependent demand on an inventory model for perishable items within a pentagonal-fuzzy framework. Using the Graded Mean Integration Representation (GMIR) method for defuzzification, the research delivered an in-depth analysis of the Total Inventory Cost function and its optimal values. The findings show that integrating product reliability and time-dependent demand into the model has a substantial effect on inventory management strategies and cost optimization for perishable products. The numerical examples and sensitivity analysis provide important insights into how changes in parameters influence optimal inventory decisions, thereby increasing the model's practical relevance. This optimization technique is particularly relevant in the food and beverage industry, where managing perishable inventory is crucial to cutting waste, ensuring product quality, and meeting shifting consumer demand. It can also be applied in the pharmaceutical sector, where product shelf life and dependability have a direct bearing on both patient safety and regulatory compliance.

Future research could build on this study by investigating several new areas. For instance, including additional factors like multi-echelon supply chains or different types of perishable products could offer a deeper understanding of inventory dynamics. Applying various defuzzification methods or advanced optimization algorithms might provide more accurate results and insights. Moreover, validating the model with real-world data could strengthen its robustness and applicability. Lastly, adapting the model to consider external factors such as market fluctuations or regulatory changes could increase its relevance and applicability across different contexts.

References

[1] Bakari, A., Bouchard, M., & Ouaret, A. (2020). Advances in perishable inventory management: A literature review. Journal of Industrial Engineering and Management, 13(3), 569-586.

[2] Bhunia, A. K., & Maiti, M. (1998). A two-warehouse inventory model for deteriorating items with a linear trend in demand and shortages. European Journal of Operational Research, 108(3), 346-356.

[3] Choudhury, S. K., Shankar, K., & Tiwari, M. K. (2008). Consensus in group decision making using evolutionary computing: A case of inventory management. Journal of Intelligent Manufacturing, 19(5), 571-582.

[4] Giri, B. C., & Chaudhuri, K. S. (2003). Optimal inventory policies for deteriorating items with time-varying demand and costs. Journal of the Operational Research Society, 54(5), 549-554.

[5] Goyal, S. K., & Giri, B. C. (2001). Recent trends in modeling of deteriorating inventory. European Journal of Operational Research, 134(1), 1-16.

[6] Li, R., & Liu, J. (2006). Inventory management with product quality and reliability. International Journal of Production Economics, 103(2), 631-643.

[7] Nahmias, S. (1982). Perishable inventory theory: A review. Operations Research, 30(4), 680-708.

[8] Singh, S. R., & Saxena, A. (2017). Fuzzy inventory model for deteriorating items with time-dependent demand under trade credit using pentagonal fuzzy numbers. Journal of Intelligent & Fuzzy Systems, 32(3), 2287-2298.

[9] Wee, H. M. (1995). A deterministic lot-size inventory model for deteriorating items with shortages and a declining market. Computers & Operations Research, 22(3), 345-356.

[10] Zadeh, L. A. (1965). Fuzzy sets. Information and Control, 8(3), 338-353.

[11] Adak, Sudip, and G. S. Mahapatra. "Effect of reliability on varying demand and holding cost on inventory system incorporating probabilistic deterioration." Journal of Industrial & Management Optimization 18.1 (2022).

[12] Mahapatra, G. S., Sudip Adak, and Kolla Kaladhar. "A fuzzy inventory model with three parameter Weibull deterioration with reliant holding cost and demand incorporating reliability." Journal of Intelligent & Fuzzy Systems 36.6 (2019): 5731-5744.

[13] Manna, Amalesh Kumar, Jayanta Kumar Dey, and Shyamal Kumar Mondal. "Two layers supply chain in an imperfect production inventory model with two storage facilities under reliability consideration." Journal of Industrial and Production Engineering 35.2 (2018): 57-73.

[14] Adak, Sudip, and G. S. Mahapatra. "An inventory model of time and reliability Dependent demand with deterioration and partial back ordering under fuzziness." International Conference on Information Technology and Applied Mathematics. Cham: Springer International Publishing, 2019.

[15] Adak, Sudip, and G. S. Mahapatra. "Two-echelon imperfect production fuzzy supply chain model for reliability dependent demand with probabilistic deterioration and rework." Journal of Intelligent & Fuzzy Systems 41.2 (2021): 3833-3847.

[16] Adak, Sudip, and G. S. Mahapatra. "Effect of inspection and rework of probabilistic defective production on two-layer supply chain incorporating deterioration and reliability dependent demand." International Journal of System Assurance Engineering and Management 12.3 (2021): 565-578.

[17] Rajput, Neelanjana, Anand Chauhan, and R. K. Pandey. "Optimisation of an FEOQ model for deteriorating items with reliability influence demand." International Journal of Services and Operations Management 43.1 (2022): 125-144.

[18] Khara, Barun, Jayanta Kumar Dey, and Shyamal Kumar Mondal. "Effects of product reliability dependent demand in an EPQ model considering partially imperfect production." International Journal of Mathematics in Operational Research 15.2 (2019): 242-264.

[19] Mahapatra, G. S., et al. "Inventory model for deteriorating items with time and reliability dependent demand and partial backorder." International Journal of Operational Research 29.3 (2017): 344-359.

[20] Kumar, Kamal. "Inventory Policy for Deteriorating Items with Two Warehouse and Effect of Carbon Emission." Reliability: Theory & Applications 16.SI 2 (64) (2021): 156-165.

[21] Yadav, A.S., Kumar, A., Yadav, K.K. et al. Optimization of an inventory model for deteriorating items with both selling price and time-sensitive demand and carbon emission under green technology investment. Int J Interact Des Manuf (2023). https://doi.org/10.1007/s12008-023-01689-8

[22] Yadav, K.K., Yadav, A.S. & Bansal, S. Interval number approach for two-warehouse inventory management of deteriorating items with preservation technology investment using analytical optimization methods. Int J Interact Des Manuf (2024). https://doi.org/10.1007/s12008-023-01672-3

[23] Mahata, Sourav, and Bijoy Krishna Debnath. "A profit maximization single item inventory problem considering deterioration during carrying for price dependent demand and preservation technology investment." RAIRO-Operations Research 56.3 (2022): 1841-1856.

[24] Mahata, Sourav, and Bijoy Krishna Debnath. "The impact of R&D expenditures and screening in an economic production rate (EPR) inventory model for a flawed production system with imperfect screening under an interval-valued environment." Journal of Computational Science 69 (2023): 102027.

[25] Yadav, Krishan Kumar, Ajay Singh Yadav, and Shikha Bansal. "OPTIMIZATION OF AN INVENTORY MODEL FOR DETERIORATING ITEMS ASSUMING DETERIORATION DURING CARRYING WITH TWO-WAREHOUSE FACILITY." Reliability: Theory Applications 19.3 (79) (2024): 442-459. https://doi.org/10.24412/1932-2321-2024-379-442-459

[26] Poswal, Preety, et al. "Investigation and analysis of fuzzy EOQ model for price sensitive and stock dependent demand under shortages." Materials Today: Proceedings 56 (2022): 542-548.