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A DETERIORATING INVENTORY MODEL WITH LIMITED VEHICLE CAPACITY, STOCK DEPENDENT DEMAND AND UNAVAILABILITY SUPPLY

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ABSTRACT

Inventory model is one research topic that has been given attention intensively in the supply chain. There are two main costs for inventory, which are transport cost and inventory cost. Therefore, some buyers would like to apply a Vendor Managed Inventory (VMI) system where vendors handle the transportation and manage stocks at the buyer's hand. The problem is complex for some items, such as fruits and vegetables, in which the items deteriorate. The need for fruits and vegetables tends to be higher as the stock is high. Deteriorating inventory models have been developed in many years, however, only a few models considering vehicle capacity, carbon emission, deteriorating items, stock dependent demand, and unavailability supply. In this study, a deteriorating inventory model for multi-items in one distribution with stock dependent demand is improved. On the other hand, fruits and vegetable stock are not consistently available, so lost sales costs should be examined. Environmental issues have been studied by many researchers. Therefore, we further consider the carbon emission yield in this model. Since the closed-loop solution cannot be obtained, we employ a simple heuristic solution in Maple. A sensitivity analysis is employed to obtain some management insight. The sensitivity analysis indicates that the carbon emission tax rate can encourage decision-makers to increase order quantity and reduce carbon emission, but the policy should deal with many features that are recognized by decision-makers to make it useful.

Keywords: inventory, deteriorating, stock dependent demand, carbon emission

1. INTRODUCTION

The inventory issues related to fresh food are more intricate compared to other sorts of items, as they possess distinct features. Initially, it is important to note that the quality of most fresh foods tends to decline and the quantity decreases as they age. Furthermore, the availability of the commodities is inconsistent. During the initial phase of the harvest season, it is challenging to acquire fully ripened items, and their cost is high. As the harvest season nears its end, the demand decreases and many crops are fully ripe. Obtaining a reliable and consistent supply from the source is of utmost importance at this stage. Furthermore, the quantity of appealing things to be placed on the rack is diminishing due to a decrease in demand and the necessity to rely on the available stock. When there is a substantial quantity of merchandise on the rack, the demand is expected to be high. This study presents a novel inventory model specifically designed for fresh food crops during the most recent harvest season.

One marketing strategy to attract consumers is to increase the stock on a display rack. The customer's inclination to purchase a product is contingent upon the quantity of things shown on the rack. This phenomenon is referred to as stock dependent demand. The stock dependent demand inventory model was initially created by Gupta and Vrat in 1986. Mandal and Phaudjar (1989) subsequently devised an economic production quantity model for degrading commodities, taking into account the consumption rate that depends on the stock level. Baker and Urban (1988) devised a model for an inventory item that deteriorates with time and has demand that depends on the stock. Pal et al. (1993) furthered their research on this model. In a study conducted by Hou (2006), the impact of inflation and temporal discounting on deteriorating inventory problems with stock dependent demand was evaluated. Lee and Dye (2012) created a model for inventory items that deteriorate with time, where the demand for these items is influenced by the current stock level. They achieved control over the pace of deterioration by implementing different technological measures. They assessed the return on investment for technology and implemented measures to reduce the rate of deterioration. Teng and Chang (2005) created a production economic quantity model specifically designed for degrading products. The researchers determined that prominently showcasing high-quality products at a grocery store might generate increased client demand and profitability. However, it is crucial to carefully manage the quantity of merchandise on display, since an excessive amount can create a bad impression among customers. In a further study, Li et al. (2017) devised a model that incorporates dynamic pricing and periodic order quantity to address the management of deteriorating items, taking into account the influence of stock-dependent demand. Shortages and backlogging are permitted, and the quantity is unpredictable and contingent on the timing of the next replenishing point.

While there is extensive research on degrading inventory models with stock-dependent demand, there are only a few studies that investigate deteriorating inventory models with both stock-dependent demand and unavailable supply. The lack of availability of certain perishable commodities, such as fruits and vegetables, is significant due to their unstable nature and inconsistent supply. Some research studies, such as Sutapa and Widyadana (2014) and Al-Salamah (2018), have examined how the absence of machines affects the supply. Another notable concern is carbon emissions, as the delivery of things necessitates the use of trucks that contribute to carbon emissions. The content of this study is organized into four distinct sections. The initial section of the paper presents pertinent literature and highlights the paper's contribution. In Section 2, various mathematical models are formulated. In Section 3, a practical example is provided together with a sensitivity analysis to offer valuable insights into the management implications of the model. The final part presents several thrilling conclusions.

2. MODEL DEVELOPMENT

This study presents a model that considers a degrading inventory system with stock dependent demand, unpredictable supply, vehicle capacity constraint, and carbon emission cost. Practically, the model outlines two criteria for products. When a company purchases Q units, these products will be depleted by customer demand and the rate of deterioration until they reach zero units at time T1. Once the inventory reaches zero, Q units are purchased to replenish the stock.

Nevertheless, there is a possibility that the supplier may be unable to meet the need and as a result, the delivery date for T_2 may be delayed. Due to the delay in delivery, there will be a financial impact in the form of lost sales costs.

Notations:

I_t	= Inventory level at t period
B	= stock sensitivity rate
d	= demand rate
θ	= deteriorating rate
K	= setup cost
H	= holding cost
S	= lost sales cost
TC	= total inventory cost
T_1	= replenishment time
T_2	= shortage time
T	= total replenishment time
Cap_i	= Capacity of vehicle i
TCT	= total cost
$F^e{}_i$	= average emission from fuel combustion of vehicle i ($kgCO_2$/liter)
T_x	= carbon emission tax (\$/$tonCO_2$)
c_1	= average vehicle fuel consumption of vehicle i (liter/trip);
e_i	= transportation emission cost of vehicle i (\$/trip);
e_1	= $c_1 F_e t_x$;

The inventory level for stock dependant demand degrading inventory can be represented by equation 1-4:

$$\frac{dI}{dt} + \theta I_t = -d(I(t)), \qquad 0 \le t \le T_1 \tag{1}$$

Where

$$d = \beta I(t) \tag{2}$$

One obtains:

$$I(t) = \frac{1}{\theta+\beta}(e^{(\theta+\beta)(T_1-t)} - 1) \qquad 0 \le t \le T_1 \tag{3}$$

Total inventory for $0 \le t \le T_1$ is

$$\int_0^{T_1} I(t)dt = \int_0^{T_1} \frac{1}{\theta+\beta}(e^{-(\theta+\beta)(T_1-t)} - 1)\,dt$$

$$= \frac{(e^{-(\theta+\beta)T_1} - \theta T_1 - T_1\beta - 1)}{(\theta+\beta)^2} \tag{4}$$

Due to the intermittent availability of supply, lost sales can occur when there is no supply left and the stock is depleted to zero. The overall inventory cost for lost sales includes the expenses associated with setup, carbon emissions, inventory holding, and the negative impact on goodwill.

The chance of lost sales is determined by the probability function f(t). Equation 5-10 represents the mathematical methodology for calculating the total inventory cost.

$$TC(T) = E\left[K + e_i + h\left(\int_0^{T_1} \frac{1}{\theta+\beta}\left(e^{-(\theta+\beta)(T_1-t)} - 1\right)\right) + S\frac{\int_{t=T_1}^{\infty} e^{-\beta t} f(t)dt}{\beta}\right] \tag{5}$$

Since $T_2 = \int_{t=T_1}^{\infty}(t-T_1)f(t)dt$, the total cost per unit time can be derived as follows:

$$TCT(T) = \frac{E\left[K + e_i + h\left(\int_0^{T_1} \frac{1}{\theta+\beta}\left(e^{-(\theta+\beta)(T_1-t)} - 1\right)\right) + S\frac{\int_{t=T_1}^{\infty} e^{-\beta t} f(t)dt}{\beta}\right]}{E\left[T_1 + \int_{t=T_1}^{\infty}(t-T_1)f(t)dt\right]} \tag{6}$$

with vehicle capacity constraint:

$$Q <= Cap_i \tag{7}$$

Where

$$Q = \frac{\beta}{\theta+\beta}\left(e^{(\theta+\beta)T_1} - 1\right) \tag{8}$$

In this study, we assume the supply availability time will follow a uniform distribution. Substitute uniform probability density function in (6), one has:

$$TCT(T) = \frac{K + e_i + h\left(\frac{(e^{-(\theta+\beta)T_1} - \theta T_1 - T_1\beta - 1)}{(\theta+\beta)^2}\right) + Sd\left(\frac{(b-T_1)^2}{2b}\right)}{T_1 + \frac{(b-T_1)^2}{2b}} \tag{9}$$

The optimal T_1 can be found by derivate (9) concerning T_1 and set the result to zero

$$\frac{dTCT(T_1)}{dT} = \frac{\left(K + e_i + h\left(\frac{(e^{-(\theta+\beta)T_1} - \theta T_1 - T_1\beta - 1)}{(\theta+\beta)^2}\right) + \frac{S\left(\beta^2 b^2 - 2T_1\beta^2 b + 2e^{-\beta b}(1+\beta b - T_1\beta) + \beta^2 T_1^{\,2} - 2e^{-T_1\beta}\right)}{2\beta^3 b}\right)\left(1 - \frac{b-T_1}{b}\right)}{T_1 + \frac{(b-T_1)^2}{2b}}$$

$$- \frac{\left(h\left(\frac{(\theta+\beta-(\theta+\beta)e^{T_1(\theta+\beta)}}{(\theta+\beta)^2}\right) - \frac{S\left(-2\beta^2 b + 2T_1\beta^2 - 2e^{-\beta b}\beta + 2\beta e^{-T_1\beta}\right)}{2\beta^3 b}\right)}{T_1 + \frac{(b-T_1)^2}{2b}} = 0 \tag{10}$$

Due to the unavailability of a closed-form solution for equation (10), a straightforward heuristic from Maple is employed to solve the problem. Due to limitations in vehicle capacity, the following measures are implemented:

Step 1: Determine the most favorable replenishment interval using equation (11).

Step 2: Determine the amount of goods transported by a truck in one trip using a value of 8 for all types of trucks, and then compare this number with the truck's capacity.
Step 3: If the order amount is less than or equal to the truck capacity (7), the best replenishment time is determined. If the condition is not met, the order quantity will be set equal to the capacity of the truck, and the replenishment period will be determined.
Step 4: Compare the aggregate cost of each vehicle category and identify the minimum cost.

3. A NUMERICAL EXAMPLE AND SENSITIVITY ANALYSIS

A numerical example is shown to illustrate the model. We use $K = 100$, a = 0.05, $h = 1$, $S = 10$ and $b = 1$ and stock dependent parameter β = 10. Some emission data are derived from Daryanto (2019) and the truck emission data ad carbon tax emission is shown in Table 1. Since the closed form solution cannot be found, the model is solved using a numerical method in Maple.
The result for each transportation type is presented in Table 2. The optimal ordering quantity for truck type 1 is 1093.3, truck type 2 = 1109.3 and truck type 3 is 1141.3, however the optimal ordering quantity for truck type 1 and truck type 2 is greater than the truck capacity. Therefore, the ordering quantity for truck 1 is equal to 500 and the ordering quantity for truck 2 is 1000. The optimal total cost is derived when using truck type 2 with ordering time (T*) is equal to 0.619 and the total cost is 158.5. The detail of the optimal solution is shown in Table 2.

Table 1. Truck emission data

Truck type	Truck capacity	Average emission tonCO_2/liter	Carbon emission tax $/ ton$CO_2$	Average fuel consumption liter/trip
1	500	2.6×10^{-3}	75	27.5
2	1000	2.6×10^{-3}	75	35
3	1500	2.6×10^{-3}	75	50

Table 2. Decisions for each truck type

Truck type	Truck capacity	Q*	T*	Total cost
1	500	1093.3	0.619	159.551
2	1000	1109.3	0.688	158.499
3	1500	1141.3	0.701	162.361

A sensitivity analysis is conducted using varies of carbon emission tax and let other parameters in the same values. The sensitivity analysis result is shown in Table 3-6.

Table 3. Solution for carbon emission tax = 60

Truck type	Truck capacity	Q*	T*	Total cost
1	500	1081.6	0.619	158

2	1000	1094.35	0.688	**156.646**
3	1500	1119.93	0.699	159.744

Table 4. Solution for carbon emission tax = 67.5

Truck type	Truck capacity	*Q**	*T**	Total cost
1	500	1087.43	0.619	158.78
2	1000	1101.81	0.688	**157.573**
3	1500	1130.59	0.700	161.053

Table 5. Solution for carbon emission tax = 82.5

Truck type	Truck capacity	*Q**	*T**	Total cost
1	500	1099.15	0.619	160.331
2	1000	1116.73	0.688	**159.426**
3	1500	1151.92	0.70199	163.668

Table 6. Solution for carbon emission tax = 90

Truck type	Truck capacity	*Q**	*T**	Total cost
1	500	1105.55	0.619	161.0981
2	1000	1124.19	0.688	**160.367**
3	1500	1162.59	0.703	164.974

Table 3-6 demonstrates that different levels of carbon emission tax do not affect the decision to use truck type 2. Consequently, the choice of truck type is not influenced by the carbon emission tax in this scenario. Nevertheless, the overall cost rises in direct proportion to the increase in the carbon emission tax. Given that the optimal ordering quantity for truck type 2 exceeds the truck's capacity, it follows that altering the carbon emission price will have no impact on the ordering quantity. Nevertheless, if the most efficient quantity to order is less than the capacity of a truck, the ordering quantity can be adjusted by altering the carbon emission fee. The analysis of vehicle type 3 reveals a positive correlation between the ordering quantity and the growth in carbon tax emissions. Implementing a higher carbon tax can incentivize decision-makers to raise their ordering quantity, hence reducing the impact of carbon emissions. Nevertheless, the carbon emission tax fails to consistently incentivize company decision-makers to modify their choices in order to reduce carbon emissions by raising their ordering quantity. The decision-maker must address several characteristics that prevent corporations from supporting carbon emission reduction, such as truck capacity in this case. Accurately setting the carbon emission tax is crucial to ensure that businesses not only incur additional expenses, but also to effectively achieve the goal of reducing carbon emissions.

4. CONCLUSION

This study presents a model that considers a degrading inventory system with stock dependent demand, inconsistent supply, truck capacity constraint, and carbon emission tax. The problem is solved using a heuristic method based on Maple due to the inability to construct a closed-loop solution. A sensitivity study is performed to validate the model and demonstrate the impact of a carbon emission tax on the quantity of orders.

The sensitivity analysis reveals that the ordering quantity remains constant despite the increase in carbon tax emission tax. This is because the optimal ordering quantity exceeds the capacity of the truck. Nevertheless, in the absence of any limitations on truck capacity, the amount of orders will rise in tandem with the increase in carbon emission tax. By increasing the quantity of orders, the impact of carbon emissions can be diminished. Hence, the implementation of a carbon emission tax policy has the potential to decrease carbon emissions; nevertheless, several factors must be taken into account to ensure its effectiveness. The model considers that the truck is capable of delivering only one item, hence vehicle type 3 delivers things that are below its capacity and is exclusively assigned to one buyer. To enhance the model, it should take into account the multi-item and routing problem.

5. REFERENCES

Al-Salamah M. (2018). Economic production quantity with the presence of imperfect quality and random machine breakdown and repair based on the artificial bee colony heuristic. *Applied mathematical Modelling*, 63, 68-83.

Baker R.C., and Urban T.L. (1988). A deterministic inventory system with an inventory-level-dependent demand rate. *J. Opl. Res. Soc.*, 39(9), 823-831.

Daryanto Y. Wee H.M., Widyadana G.A. (2019). Low carbon supply chain coordination for imperfect quality deteriorating items. *Mathematics*, 3(7), 234.

Gupta, R., Vrat, P. (1986). Inventory model for stock-dependent consumption rate. *Opsearch*, 23, 19-24.

Hou K. L. (2006). An inventory model for deteriorating items with stock-dependent consumption rate and shortages under inflation and time discounting. *European Journal of Operational Research,* 168, 463-474.

Lee Y.P. and Dye C.Y. (2012). An inventory model for deteriorating items under stock-dependent demand and controllable deterioration rate. *Computers & Industrial Engineering*, 63, 474-482.

Li Y., Zhang S., and Han J. (2017). Dynamic pricing and periodic ordering for a stochastic inventory system with deteriorating items. *Automatica*, 76, 200-213.

Mandal B.N. and Phaudjar S. (1989). An inventory model for deteriorating items and stock-dependent consumption rate. *J. OPl. Res. Soc*., 40, 483-488.

Pal S., Goswami A., and Chaudhuri K.S. (1993). A deterministic inventory model for deteriorating items with stock-dependent demand rate. *International Journal of Production Economics*, 32, 291-299.

Sutapa N., Widyadana G.A. (2014). The effect of unreliable machine for two echelons deteriorating inventory model, *Jurnal Teknik Industri*, 16(2), 107-112.

Teng J.T., and Chang C.T. (2005). Economic production quantity models for deteriorating items with price-and stock-dependent demand. *Computers & Operations Research*, 32, 297-308.