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Deterministic Model For Blood Bank Inventory Control With Increasing Demand And Logistic Considerations Using Multi-Objective Optimization

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Abstract: This paper presents a deterministic model for the inventory control of blood bank storage systems, accounting for item deterioration with increasing demand, and the effects of inbound and outbound logistics, ramp time demand, and inflation. The inventory level in the blood bank at any time t, denoted$P_{BS}(t)$, is managed under a fixed capacity δw using multi-objective optimization with changing the rate of level. The model permits stock-outs, which are partially deferred, and incorporates a variable rate of deterioration. This paper discusses the mathematical modeling of blood consumption rates and replenishment points in blood bank storage. The differential equation for the rate of change in $P_{BS}(t)$, over time is solved using MATLAB.

Key words: Blood storage, Inventory, MATLAB, demand etc.

Introduction: The primary purpose of blood bank storage is to ensure the availability of blood for patients in need. A blood bank is an institution that collects, tests, processes, and stores blood for future use. Yadav, Ahlawat, Sharma, and Swami (2020) developed a reliable system for blood storage and inventory control to maximize efficiency. The healthcare systems for blood bank storage have a fixed capacity of δw units, utilizing reliability applications and a multi-objective optimization genetic algorithm.

Yudianti, Lestari, and Darma (2021) designed a method for controlling the optimal supply of disposable medical materials at the Bali Mandara Eye Hospital. Their results showed a 19.14% decrease in the total cost of inventory after applying the Economic Order Quantity (EOQ) method. The Reorder Point (ROP) method effectively prevented stockouts.

Paul, Chowdhury, Chakrabortty, and Sallam (2022) developed a stochastic mathematical model to optimize recovery for a three-stage supply chain (SC) exposed to the multi-dimensional impacts of the COVID-19 pandemic. This model addresses simultaneous demand, supply, and capacity uncertainty in a multi-stage SC recovery context and employs a chance-constrained programming approach with an enhanced multi-operator differential evolution variant-based solution.

Mani, Annadurai, Danasekaran, and Ramasamy (2014) analyzed drug categorization based on cost and criticality, identifying the required level of managerial control. Rahim, Hassan, and Radzuan (2018) focused on inventory management in a healthcare product manufacturing company in Kedah, Malaysia. They used a case study approach to conduct an initial inventory assessment through ABC analysis for efficient inventory control.

T and A (2017) optimized overall inventory demand using quantitative forecasting techniques. The study applied ten forecasting techniques with Risk Simulator Software, identifying data patterns before applying the methods. Barma, Biniyamin, and Modibbo (2022) developed a mixed-integer optimization model for municipal solid waste (MSW) management in Kano State, Nigeria. Their model optimized total costs, including transportation and facility operation costs, and recommended establishing collection and treatment centers with specific capacities.

Manhas, Haroon, Sheikh, and Syed (2012) conducted a study revealing the annual consumption and classification of drugs based on expenditure. They found that 15.38% of drugs consumed 70% of the annual budget (group A), 22.43% consumed 20% (group B), and 62.17% consumed 10% (group C). VED classification further categorized these drugs into vital, essential, and desirable.

Kritchanchai and Meesamut (2015) developed a hospital inventory management system to minimize total inventory costs while maintaining patient safety. They proposed the most suitable policies for each drug category based on historical demand and clinical importance. Hani, Basri, and Winarso (2013) observed inventory management and distribution of medical consumables in a public hospital, identifying key factors for efficient management.

Torkayesh, Vandchali, and Tirkolaee (2021) formulated a multi-objective optimization model to help companies make optimized decisions considering economic, environmental, and social aspects. Yılmaz (2018) contributed to the optimal level of drug storage by evaluating annual drug expenditure using ABC and VED analysis.

Sharma and Baghel (2023) discussed an optimized Artificial Neural Network (ANN) for inventory modeling, employing the k-means algorithm to create homogeneous item groups for uniform inventory control policies. Monov and Tashev (2011) presented several inventory control algorithms implemented as software modules in MATLAB.

Ramírez and Labadie (2017) studied inventory control and distribution of blood products, formulating optimization models to minimize total cost and shortages. Swami, Richa, and Ahlawat (2023) provided an economic model addressing production and poverty factors. Yadav, Ahlawat, Agarwal, and Pandey (2020) focused on predicting stock levels in the red wine sector to reduce total supply chain costs.

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Preliminary:
Let we
$P_{BS}(t)$ = Inventory level in blood bank storage any time$t$.
$D(t) = (\alpha_0 - 1)e^{-(\beta-1)t}$, $(\alpha_0 - 1) > 0, (\beta_0 - 1) > 0$, Demand rate $D(t)$at time t.
δ_w = The capacity of the blood bank storage.
q = The ordering quantity per cycle.
$(\pi_0 - 1)$= Inflation rate.
q_{IBL}= Inbound logistics cost per unit per unit time.
q_{obl}= Outbound logistics cost per unit per unit time.
C_{bhc}= The holding cost per unit per unit time in blood bank storage.
C_{bdc} = The deteriorate cost per unit.
C_{bsc} = The shortage cost per unit per time.
C_{ols}= The opportunity cost due to lost sale.
$(\mu_0 - 1)$= The replenishment cost per order.
TBC= Total cost blood bank storage.
Now the formulation of the problem

$\frac{dP_{BS}}{dt} = -(\beta - 1)(t)P_{BS}(t) \qquad 0 \le t \le t_1$………………….(1)

$\frac{dP_{BS}}{dt} + (\beta - 1)(t)P_{BS}(t) = -D(t)$ ………………………(2)

We have

$$D(t) = (\alpha_o - 1)e^{-(\beta_o-1)t}$$

$\frac{dP_{BS}}{dt} + (\beta - 1)(t)P_{BS}(t) = - (\alpha_o - 1)e^{-(\beta_o-1)t} t_1 \le t \le t_2$…………..(3)

$$\frac{dP_{BS}}{dt} = - (\alpha_o - 1)e^{-(\beta_o-1)t}e^{-(\pi_o-1)t} t_1 \le t \le t_2$$

$P_{BS}(0) = \delta_w$ and $P_{BS}(t_2) = 0$

Now the solution of equations (1), (2) & (3) and get the solution

$$logP_{BS}(t) = -(\beta - 1)t^2/2$$

$$P_{BS}(t) = e^{-(\beta-1)t^2/2} 0 \le t < t_1 \text{……………………. (4)}$$

At $t = 0$ the initial point the storage is $\delta_w = 1000$ units. According to the time the storage level will be decrease; the study is showing in the closed interval of $[0, t_1, t_2]$. We divide this interval in two sub intervals$[0, t_1]$and$[t_1, t_2]$.

Result and Analysis: In this paper we discuss about the mathematical modeling of a consumption rate of blood from storage level and replenishment point.

$$\frac{dP_{BS}}{dt} = -(\beta - 1)(t)P_{BS}(t) \qquad 0 \le t \le t_1$$

Rate of change in the P_{BS} according to the time interval solve with the help of MATLAB software. Here we define the function to change the consumption of blood with respect to time. We will analysis the different stage of coefficient and change in the inventory level of blood storage at time. The figure 1 is showing the change in the P_{BS} with respect toβ. By the equation (2) , plotted the graph of differential according to change in the coefficient β. We find that the value of coefficient taken in the range of $1 \le \beta \le 2$. With increase in the value of β the decreasing rate of P_{BS} is deistically change and the decrease in the amount very vastly. At the value $1.5 < \beta \le 2$& the storage of blood is finish under four days. But at the $\beta = 1.5$ the finish time is increased with four days. So the optimum coefficient for the inventory consumption is 1.5 and now we generate a relation with another coefficient α as initial storage coefficient.

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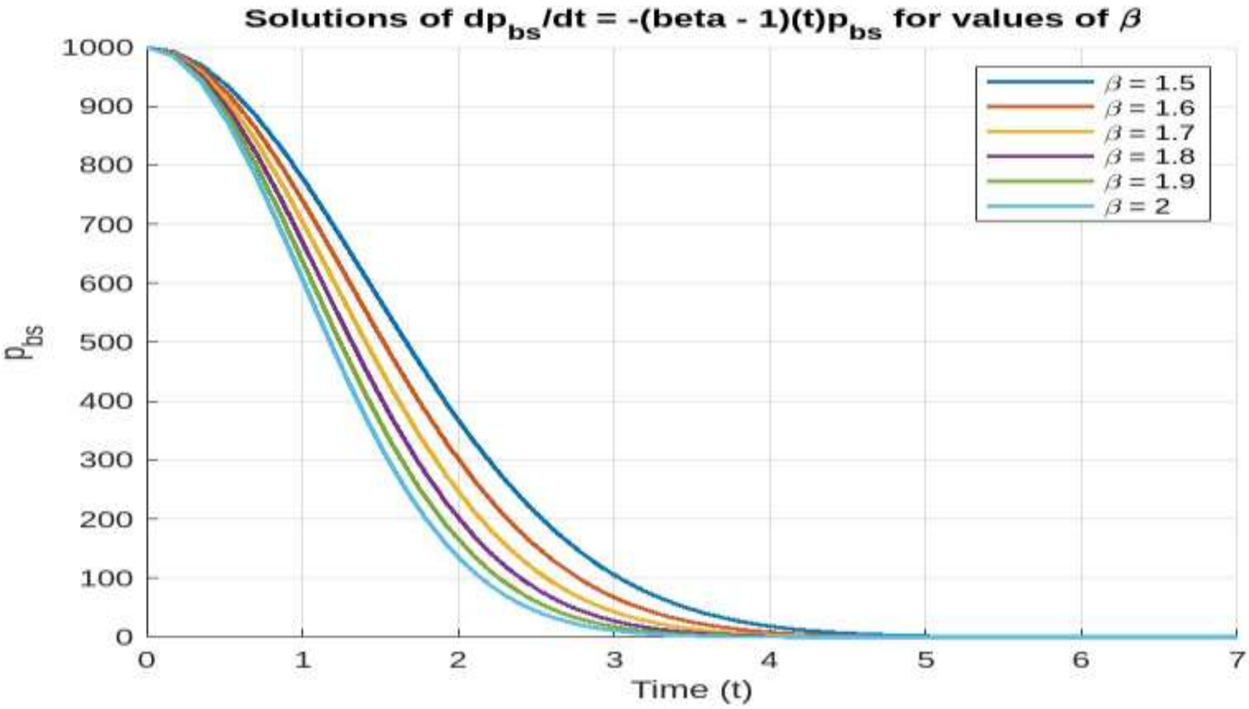

Fig.1

The figure 3 is indication the optimistic value of β at 1.5 and now with the help of equation (2), we draw the graph in MATLAB software. In this graph first we take the value of $\beta = 1$ and α values are different like $\alpha_o = 1, 1.2, 1.4, 1.6, 1.8, 2$. Here we find the drastically change in inventory storage value on different values of α_o.

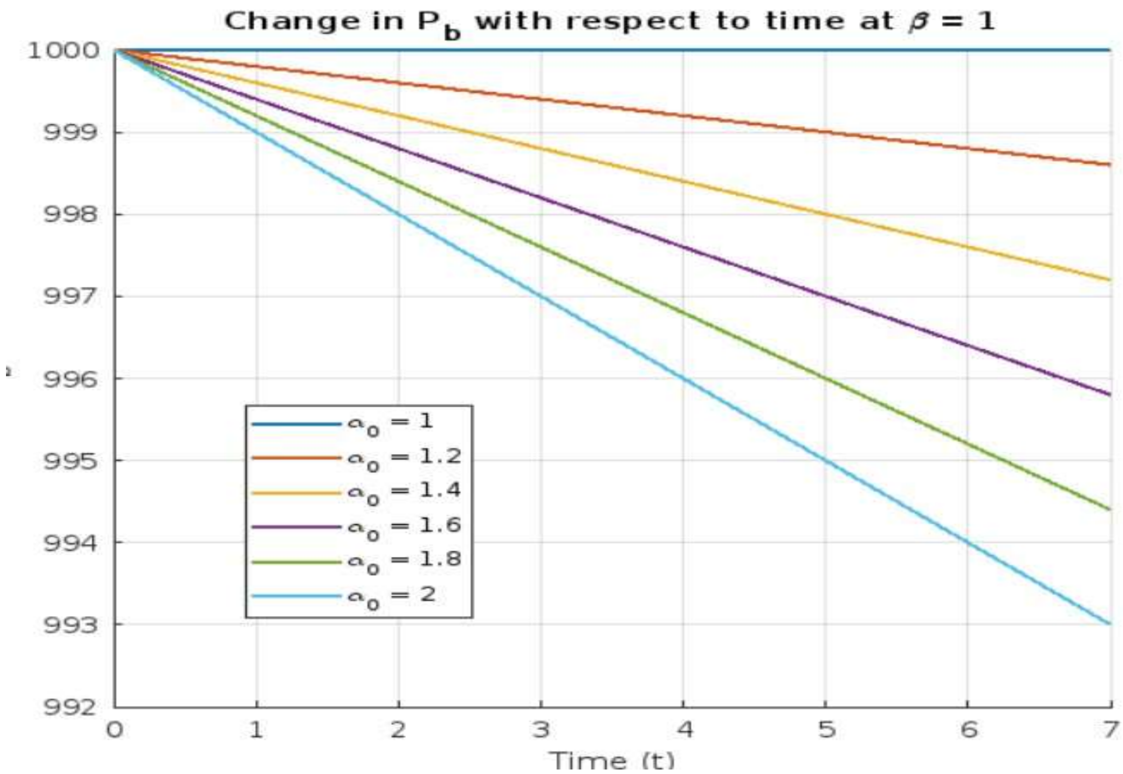

Fig.2

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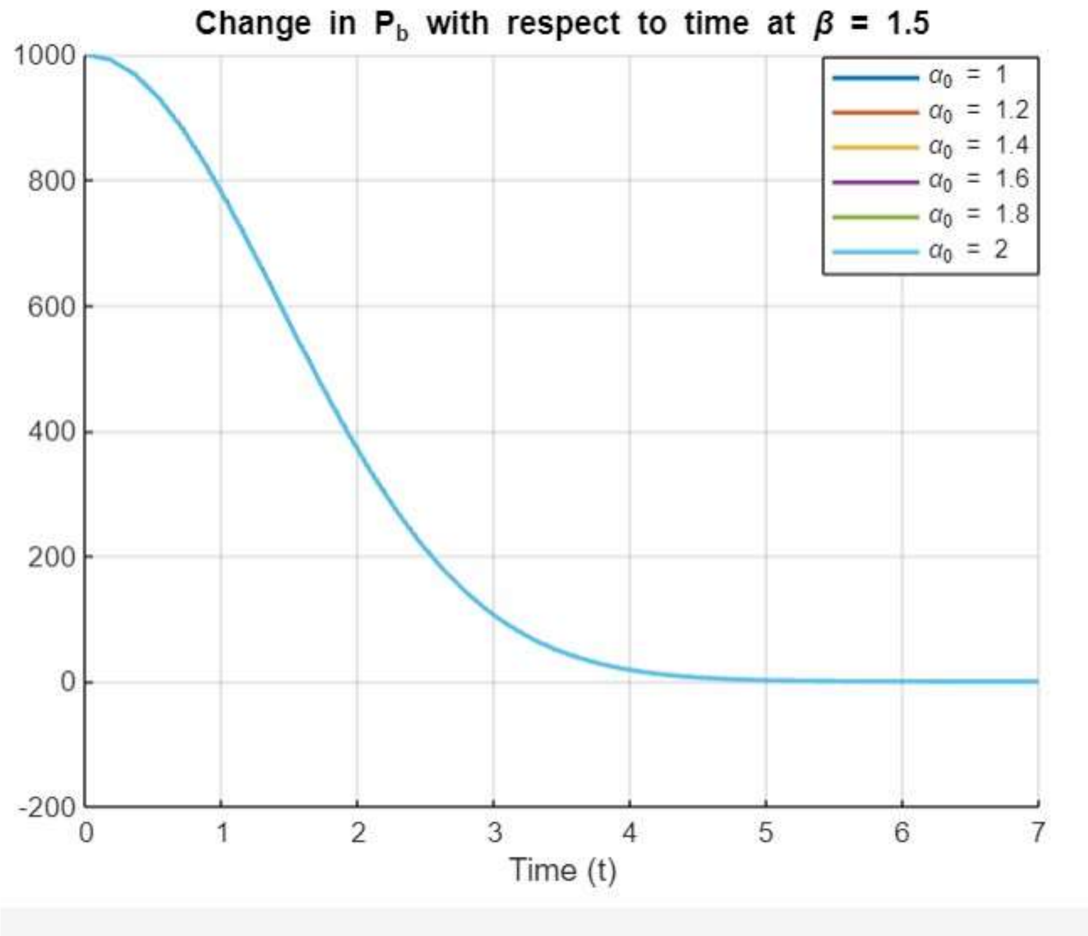

Fig.3

In fig.3 the value of β coefficient is fixed at 1.5 and the value of $\alpha_o$are varied from $1\ to\ 2$. The fig. 3 shows that the all value $\alpha_o$coincide on $\beta = 1.5$.

Conclusion: This paper is focused on the blood bank storage level consumption and decreasing with demand rate. In this paper we are showing the consumption rate and the point where the restoring should be start. The article is visualizing the result with graphical presentation of inventory level in blood bank storage at time t . Here we find the optimum value of β in P_{BS} consumption rate equation at 1.5. According to plot graph with the constant rate of consumption without filling at different value of coefficient $1.5 < \beta \leq 2$, P_{BS} level is decrease drastically and storage level will be empty under three days but at $\beta = 1.5$ the decreasing rate can be extend till four days and that may be point for restore the blood for next cycle.

Conflict: There is no conflict between authors.

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