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Expansion of logistics capability in emergency care systems with growing demand

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Abstract

Due to increase in population, income, or gross domestic product in the country, several systems that require fixed installations for user assistance, such as telephone and power services, port terminals, schools, water supply, among other, are subject to increased demand over time. Thus, the supply of services tends to undergo a process of saturation, and that will eventually create a need to expand their facilities over time. Emergency care services, such as firefighters, ambulance service, police, transport of organs for transplantation, etc., can also face this same problem of excessive demand over time, up until they are not able to assist the population properly. The objective of this study is to determine the optimal time interval for the inclusion of new bases for the Fire Department in the city of Florianópolis, SC, Brazil. So as to minimize the cost of the current amount needed to provide future capabilities or to make the average waiting time to assist citizens affected by some emergency situation the shortest possible. New facilities are presumed to be added to the system capacity as soon as it reaches the point of saturation or when the average waiting time in the queue for assistance exceeds a maximum due time established according to the growing demand for services. The cost of unmet demand is not included in this study.

Keywords: Logistic; Emergency Systems; Expansion.

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1. Introduction

Within the studies of transport and logistics, capacity expansion models are mathematical routines that seek to determine a priori when a system is expected to expand, considering that it has reached its maximum service capacity and has thus reached its saturation point. They are divided into deterministic models, when the exact equation of demand growth is known, and probabilistic models, in which demand can vary around a trend line. Studies on determining the optimal time interval between capacity enhancements were started by Manne (1961), who considered demand growth to be a linear function. Srinivasan (1967) adapted Manne's process, assuming a geometrical growth rate. Freidenfelds (1980) added the queuing theory and studied the problem of capacity expansion as a random process of birth and death showing that it is possible to adapt the stochastic model of demand growth to a deterministic model. Taborga (1969), also by using stochastic processes, proposed a model to plan the development of seaports. Using mathematical programming, Novaes (1978) has developed an expansion plan in stages for a port terminal, by especially taking into account the costs of waiting and unmet demand. Models can also be used to predict the expansion of emergency care systems.

2. Main idea

Whenever the demand rises to the point where the maximum service capacity of an existing facility is reached, a new capacity is added. The excess demand behaves as an inventory *saw tooth* replenishment, where $t_0, t_1, t_2, \ldots t_n$ are time intervals in which a new capacity *x* is added to the system. If, for convenience, a physical unit of capacity and demand is adopted as equal to a year of demand growth, this toothed cycle will repeat itself every *x* years. Figure 1 shows the evolution of excess capacity over time, where such excess or available inventory is observed to be "consumed" with increased demand (Constant demand – Fixed intervals for inventory replenishment).

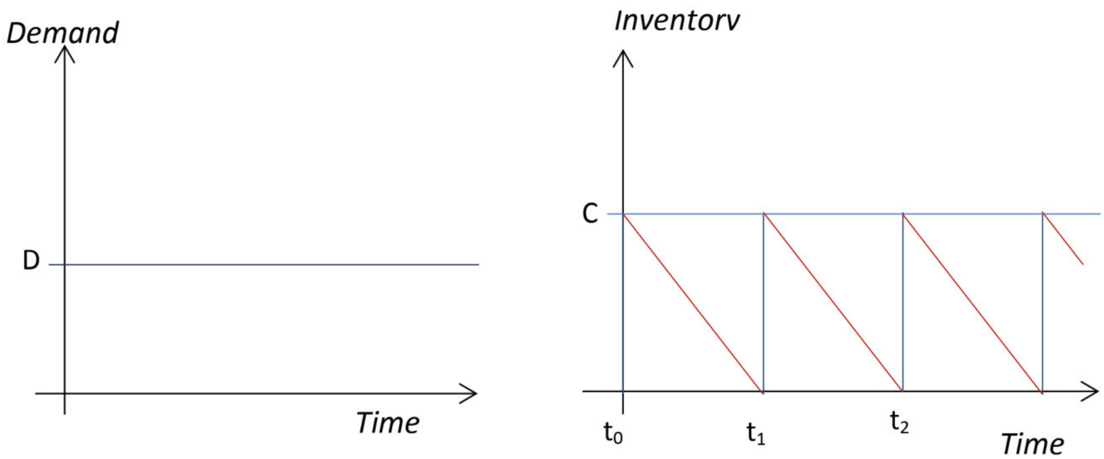

Figure 1

When demand has the tendency to increase, which may be either linear or not, the problem changes and two options come up: The first would be to keep the capacity replenish lots at a constant size, with replenishment time intervals gradually decreased; and the second option would be to keep the time intervals for inventory replenishment constant, however, to always meet the demand, replenish lot size would have to be altered at each fixed time interval. Figure 2 illustrates this situation.