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## INVENTORY CONTROL WITH A SINGLE DELIVERY OF A RESOURCE

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One of the important techniques for increasing effectiveness of an enterprise activity consists in optimisation of delivery, storage and usage of resource inventory in terms of product manufacturing, and also it consists in finding relationships between the amount of production and inventory of final products depending on internal and external conditions. The reason of necessity in solving such problems may be as follows: changing of market conditions for resource delivery, changing of product demands, mismatch between the speed of production and resource provision needs, etc.

Inventory control problems may be of different types according to number of resources and deliveries and the type of inventory deliveries (momentary and long-lasting; uniform, irregular or discrete usage of resources in time, etc.)

Corresponding mathematical model is built depending on the type and content of problem statement. Existing methods are used in regard to the model, or novel ones are developed for problem solving. The model of the problem severely depends on the type of parameters, either they are independent unknown variables, or specified values, or functions from other parameters. In most cases, these problems are considered to be non-linear.

**Example:** an enterprise (for instance, bakery) gets a single momentary delivery of $S$ units of raw materials (for instance, flour) into its storage from a supplier. The final goods are produced (for instance, bread) from these raw materials. It is known that the enterprise seamlessly processes the obtained materials with the speed of $q(t)$. The period of time $T$ needed for processing of all the materials $S$ should be determined along with the total cost of expenses $z$ for a single delivery and storage of materials during the period of their processing $T$, assuming that the delivery cost $c_п$ of material unit for a single delivery and the storage cost $c_з$ of material unit for the specified time unit during the whole processing period are known. Fig. 6.3 shows an example of irregular material processing under condition of a single delivery with quantity $S$ at the beginning of the period $T$ (at the moment when $t$=0). Consider the total delivery cost of material consignment $S$ plus its storage cost during the period $T$:

$$Z = c_p S + c_z \int_0^T \left[S - s(t)\right]dt = c_p S + c_z \int_0^T \left[ S - \int_0^t q(\tau)d\tau \right]dt$$

where $T$ is the duration of material processing;
$c_p$ is the cost of delivery of one material unit;
$c_z$ is the cost of one material unit storage during the time unit;
$q(\tau)$ – processing speed;
$s(t)$ – material remainder in store at the moment of time $t$.

The constraint for this problem consists in a fact that all the materials are totally utilized during the time $T$.

$$\int_0^T q(t)dt = S \cdot$$

This equation allows finding the time $T=\varphi[q(t),S]$ needed for overall processing of the whole material inventory $S$ if $q(t)$ is specified. The speed $ds(t)/dt=q(t)=q$ remains unchanged all the time $T$ in case of uniform processing.

The following equations can be obtained from two previous expressions:

$$T = S / q$$

$$Z = c_p S + c_z \int_0^T \left( S - \int_0^t q d\tau \right) d\tau = c_p S + 0.5 c_z ST = c_p S + 0.5 c_z S^2 / q$$

If the processing speed $q(t)=at$ increases linearly from 0 to $aT$ during the period $T$, then the following is obtained from the two equations mentioned at the beginning:

$$\int_0^T atdt = 0.5aT^2 = S,\ T = \sqrt{\frac{2S}{a}},$$

$$Z = c_p S + c_z \int_0^T \left( S - \int_0^t a\tau d\tau \right) dt =$$

$$c_p S + c_z \int_o^T \left( S - 0.5at^2 \right) dt = c_p S + c_z \left( ST - 0.167aT^3 \right).$$

The following equation is got by substituting the expression $T = \sqrt{\frac{2S}{a}}$ into the last one:

$$Z = c_p S + 0.667 c_z S \sqrt{\frac{2S}{a}} = \left( c_p + 0.667 c_z \sqrt{\frac{2S}{a}} \right) S$$

If the cost of delivery $c_p$ does not depend on the quantity of delivery $S$, then

$$Z = c_p + 0.667 c_z S \sqrt{\frac{2S}{a}}$$

In case when processing intensity linearly decreases during the period $T$ $q(t)=a(T-t)$ from $q_0=aT$ to 0, then the same is obtained from the two first expressions as under uniform increase of processing speed:

$$\int_0^T a(T-t) dt = 0.5aT^2 = S,\ T = \sqrt{\frac{2S}{a}},$$

$$Z = c_p S + c_z \int_0^T \left( S - \int_0^t a(T-\tau) d\tau \right) dt = c_p S + c_z \left( ST - 0.5aT^3 + 0.333aT^3 \right) =$$

$$c_p S + c_z \left( ST - 0.167aT^3 \right) = \left( c_p + 0.667 c_z \sqrt{\frac{2S}{a}} \right) S.$$

By analogy, period $T$ and function $Z$ can be defined for other variants of material processing speed during the period $T$. For instance, if the speed increases linearly $q(t)= q_0 +at$ from $q_0$ at the beginning of the period $T$ to $q(T)= q_0 +aT$ at the end of the period $T$, then the following is got from the two first equalities:

$$\int_0^T \left(q_0 + at\right)dt = q_0 T + 0.5T^2 = S,\ T = \sqrt{\left(\frac{q_0}{a}\right)^2 + \frac{2S}{a}} - \frac{q_0}{a},$$

$$Z = c_p S + c_z \int_0^T \left[ S - \int_0^t \left(q_o + a\tau\right)d\tau \right]dt = c_p S + c_z\left(ST + 0.5q_0T^2 - 0.167aT^3\right),$$

and if it decreases linearly $q(t)= q_0 - at$ from $q_0$ at the beginning of the period $T$ to $q(T)= q_0-aT$ at the end of the period $T$, then the following is got from the same expressions

$$\int_0^T \left(q_0 - at\right)dt = q_0 T - 0.5T^2 = S,\ T = \sqrt{\left(\frac{q_0}{a}\right)^2 - \frac{2S}{a}} + \frac{q_0}{a},$$

$$Z = c_p S + c_z \int_0^T \left[ S - \int_0^t \left(q_0 - a\tau\right)d\tau \right]dt = c_p S + c_z\left(ST - 0.5q_0T^2 - 0.167aT^3\right).$$

In the latter case, all the material consignment will be processed if condition $\left(q_o / a\right)^2 \ge 2S / a$ is held.

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