Dynamic Capacity and Location Planning of Physical Distribution Systems

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The model system is an approach to solve the dynamic multilocation warehouse (or plant) sizing problem by integrating different models and methods:

(1) A simulation model of System Dynamics type for analyzing effects of different locations and capacities on demand, cost and operating results;

(2) An Integer Programming model for determing warehouse configurations, i.e. effective locations, and capacities.

The model system has been applied to an important German wholesale distributor of pharmaceuticals. It has been used for analyzing the firm's distribution system, and working out proposals in order to improve it.

In the long run a distribution system can be defined as dynamic; it changes with progress of time. For analyzing such time-variant systems System Dynamics, developed by Jay W. Forrester , is considered as an appropriate method.

First of all it should be noted that for realizing warehouse configurations of physical distribution systems two extreme alternatives exist:

(1) many small warehouses (of type I),
(2) few large warehouses (of type II).
The effect of the various warehouse sizes on demand growth is different. This hypothesis is central to our problem and is validated with empirical data.

The diagram of Fig. 1 represents simple causal hypothesis for warehouses of type I.

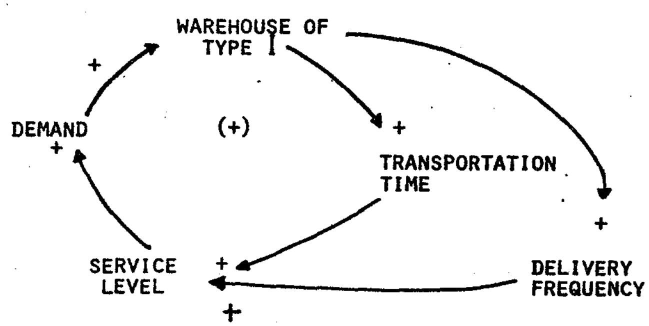

FIGURE 1: LOOP 1A+B, WAREHOUSES OF TYPE I (SIZE IS CONSTANT, AND NUMBER IS VARYING).

An increase of number of warehouses of type I in a given area influences positively the transportation time between a specific supplying depot and the retail pharmacist, and enables the wholesaler to offer more deliveries per day. Faster delivery and higher delivery frequency allow a better service. A more attractive service usually will increase the level of demand. Finally permanent increase of demand leads - in the long run - to the opening of a new warehouse.

An analysis of the increase of type II warehouses[1)] shows the following main implications: Large capacities make it possible to automate the picking up of pharmaceutical products. A higher level of automation reduces the time between incoming orders and delivery, and deminishes the rate of defective deliveries etc..

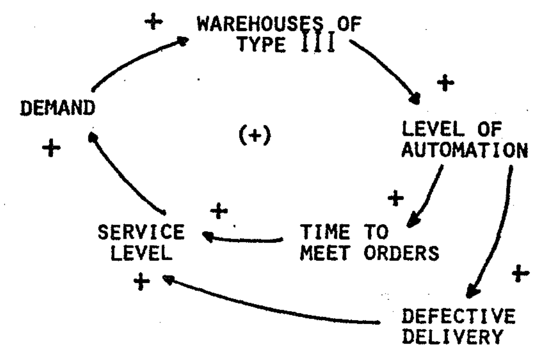

FIGURE 2: LOOP 2 A+B WAREHOUSES OF TYPE III (INCREASE IN NUMBER OF WAREHOUSES AND/OR CHANGE FROM TYPE I TO TYPE II).

Of cause a lot of other relationships are incorporated in the model. For instance a change from several small warehouses to one or two large warehouses would cause longer transportation times and less calls per day with the effect of decrease in demand.

Figure 3 demonstrates the connection between capacity utilization and demand.

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1) i.e. increase in number of warehouses and/or change from type I to type II.

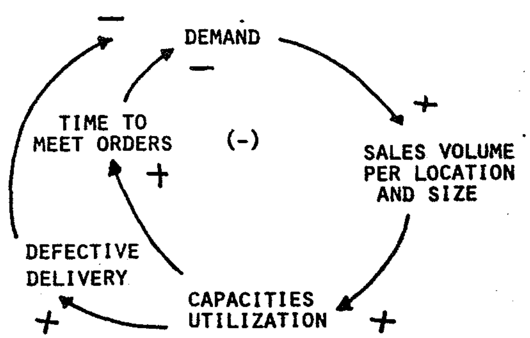

FIGURE 3: LOOP 3 A+B, DEMAND AND CAPACITY UTILIZATION

A rise in demand increases sales volume in the supplying depot which in turn leads to an increase of capacity utilization. Slowly this results in an overcharge of capacity which produces more defective deliveries and longer times to meet orders. Such a lowering of service level has a negative effect on demand.

At a certain demand level the loop of figure 3 attempts to maintain demand at a fixed value or goal despite of external influences to the contrary. Such a loop is negative or goal-seeking.

Figure 3 shows the usefulness of and the necessity for integrating an other solution method into the System Dynamics model. At some point in time one or more existing facilities of a certain size are not sufficient enough to meet a growing rate of incoming orders. In this case management has to decide, if a new warehouse should be opened or if an existing warehouse should be expanded. That is the point where e.g. an integer programming approach may be applicated. System Dynamics as an approach for simulating continuous changes alone is not the right tool for handling such discontinous problems.

The model system is implemented on a CDC 6600 computer.