OPTIMISATION OF INTERMEDIATE STORAGE NETWORK OF JIT PURCHASING

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Abstract: The supply system of cooperated production and service companies is generally a multi-stage, multi-user system. In this case components first get from the suppliers to intermediate storage places and users are supplied from there just in time. The study deals with the specification and solution of the tasks involved in the control of this multi-stage, multi-user supplier system, especially from the point of view warehousing functions of the system: organisation of order for each component on the basis of user demand; definition of structure of suppliers, intermediate storage network and users; ingoing transportation into warehouses; delivery from warehouses to users. The author describes a mathematical model, by the aid of which it is possible to define a suitable optimisation method to solve the problem.

Keywords: just-in-time, logistics, optimisation, warehousing

1. Introduction

The manufacturing and service processes today require faster response, more intensive information flow from the customer, and greater product variety than ever before. Manufacturers deal with increased sources of competition vying for the customers' favour [1.]. Coordinating manufacturers, suppliers, retailers and other participants of this global system is one of the main issues of supply chain management. [2.] There have been various studies on the factors which affect the capability of warehouse logistics: material management [3., 4.], support for operations [5.], facility management [6.], manpower management [7.], quality management [8., 9., 10.], logistics information systems [11.], maintenance [12., 13., 14.]. There are four process elements in the supply chain which influence the efficiency of the production: processing, inspection, material handling and delay. The improvement of these elements can help to increase the efficiency of production. Within the frame of this paper the author focuses on the warehousing functions of just-in-time delivery. JIT basically means a strategy of production and logistics which brings about the increase in efficiency avoiding the increase of time and cost. The main advantages of the JIT system are as follows: reduces significantly the transmission time, safe production can be created with a minimum of stock, provides possibility of responding faster to the needs of the market. The JIT production concept gives effective support for these aims. JIT basically means a new strategy of production and logistics which brings about the increase in efficiency avoiding the increase of time and cost. It is the virtual enterprise that creates the actual real environment for JIT-delivery and production as it can successfully provide the two main conditions of JIT-delivery; the integrated information processing and procurement parallel with the production.

2. JIT delivery with intermediate storage network

The coordination of just in time delivery systems is generally made by logistic service enterprises. They coordinate and make more efficient the material flow among the participants of the supply chain and increase the utilization of the logistic capacities. The actual (physical) running of the material flow (e.g. transport, storage, loading, etc.) is not carried out by the logistic centre but by any of the production, delivering, storing or distributional companies. The logistic service enterprise does the dispositioning, controlling and registration of all functions, therefore it only means the operation of the information flow. The models for the logistic planning and control of the logistic networks incorporate only the global problems but they have to be accommodated to the internal logistics of the individual elements.

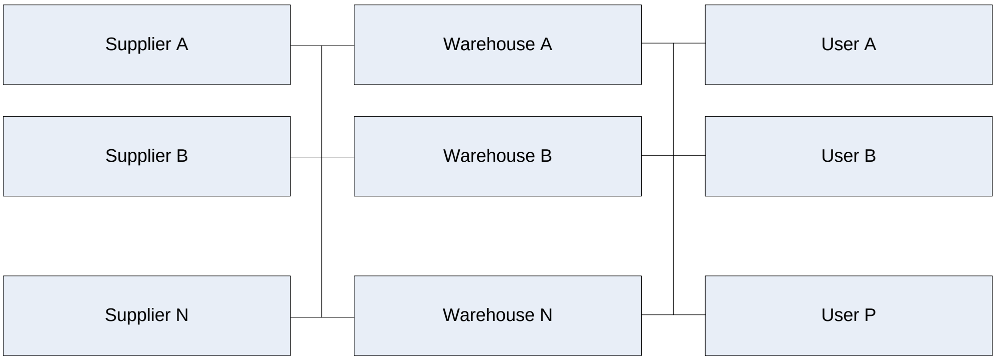

Figure 1: Model of networked supply chain with intermediate storages

The main elements of the model for global logistic planning and control encompass the following factors:

- formation of the supplier system of production companies,
- choice of methods of transport and companies for distribution,
- formation of the order of satisfying orders,
- scheduling of distribution, matching the devices for transport and loading, for making unity of stack to each task,
- determining the level of stock of the received goods (raw materials, components, etc.),
- optimum layout of collection and distribution centres, determining the level of stock,
- choosing the enterprise carrying out the distribution and choosing the destination of the distributed lots,
- scheduling the delivery into and out of the collection-distribution storage places,
- choosing the system of information flow related to the material flow.

The most important element of the model for the global logistic planning and control is to examine which tasks must be carried out autonomously by the individual companies and which tasks belong to the sphere of authority of the logistic service enterprise.

The following factors must be taken into consideration and analysed:

- Which elements of the logistic service company must belong to the decision making task of the centre?
- Which tasks of the individual companies must be drawn into the sphere of operation of the centre?

The application of the logistic service enterprise may be especially advantageous in the case of the following tasks:

- joint procurement and order of certain goods,
- joint distribution of certain goods and materials,
- joint solution to the storage of certain goods and materials,
- ensuring the logistic capacity for certain logistic tasks.

Management strategies must find answers to the following questions:

- What principles should be followed when doing procurement, deliveries, choice of partners?
- What principles should be followed when choosing those who carry out the task of transport, delivery and other logistic processes?
- What principles should be followed when matching the particular tasks with the logistic equipment?
- When choosing the route and order of service?
- When determining the level of stock at the collection-distribution storage places?

The accountancy matters between the members of the supply chain network can take one of the following two forms:

- The logistic service enterprise purchases components from the supplier and writes out the invoice when it gets to the user. The logistic service enterprise gets paid for the logistic service.
- The raw material will not be become the property of logistic centre, the user will pay its price to the supplier after its delivery. The logistic service enterprise will get a fee
  for the service it provides, which depends on the quality of the service (e.g. the shortest ingoing transportation and delivery times possible).

The supply system is generally a multi-stage, multi-user system (fig. 1.). In this case the components gets from the suppliers to intermediate storage places and users are supplied from there just in time.

3. Mathematical modelling

The intermediate storages are parts of a logistic service company, which offer services both for the component suppliers and for the users. The return of the logistic service company depends on the price of components sold to the users and the fees of the logistics services. The expenses of the logistic service company include the price of components and the costs of logistic operations, such as transportation, warehousing and material handling.

$$C = C^P + C^T + C^W \Rightarrow \min . \tag{1}$$

where

- C^P is the purchasing costs,

- C^T is the transportation cost,
- C^W is the warehousing cost.

It has to be taken into consideration that purchasing cost of components depends on the order time and order amount. Provided that user demand does not change in time, purchasing costs can be given with the following formula for a time period:

$$C^P = \sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{k=1}^{p}\frac{T_0}{t_{ijk}}\cdot q_{ijk}\cdot \phi_{ijk}^{P}\left(\tau_{ijk};q_{ijk}\right) \tag{2}$$

where

- n is the number of components,
- m is the number of suppliers,
- p is the number of warehouses,
- T_0 is the time period of optimisation,
- ϕ_{ijk}^{P} is the specific purchasing cost of component i from supplier j transported to warehouse k, which depends on time and order amount,
- t_{ijk} is the delivery frequency of component i from supplier j to warehouse k,
- τ_{ijk} is the order time of component i from supplier j to warehouse k,
- q_{ijk} is the order amount of component i from supplier j to warehouse k.

Transportation costs have two components: the cost of transportation between suppliers and storage places and the cost of transportation between storage places and users.

$$C^T = \sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{k=1}^{p}\sum_{l=1}^{q} x_{ijkl}\cdot\left(\frac{T_0}{t_{ijk}}\cdot\left(ent\frac{q_{ijk}}{CAP_{ijk}}+1\right)\cdot\left(c_{jk}^{Ts}\cdot d_{jk}+C_{jk}^{Tb}\right)+\frac{T_0}{t_{ikl}}\cdot\left(ent\frac{q_{ikl}}{CAP_{ikl}}+1\right)\cdot\left(c_{kl}^{Ts}\cdot d_{kl}+C_{kl}^{Tb}\right)\right) \tag{3}$$

where

- q is the number of users,
- CAP_{ijk} is the capacity of the transportation vehicle for component i from the supplier
  j to the warehouse k,
- CAP_{ikl} is the capacity of the transportation vehicle for component i from the warehouse k to the user l,
- t_{ikl} is the frequency of delivery of component i from warehouse k to user l,
- c_{jk}^{Ts} is the specific transportation cost from supplier j to warehouse k, which is a function of order time,
- c_{kl}^{Ts} is the specific transportation cost from warehouse k to user l, which is a function of order time,
- d_{jk} is the distance between supplier j and the warehouse k,
- d_{kl} is the distance between warehouse k and user l,

- C^{Tb}_{jk} is the basic transportation cost from the supplier j to warehouse k,
- C^{Tb}_{kl} is the basic transportation cost from the warehouse k to user l,
- x_{ijkl} is the relationship-matrix among components, suppliers, warehouses and users.

The storage costs of the logistic depends on the specific storage costs in the warehouses, the order amount of components from suppliers and warehouses and the frequency of orders.

$$C^S = \sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{k=1}^{p}\sum_{l=1}^{q}\left(T_0^2 \cdot c_{ik}^{Ss} \cdot x_{ijkl} \cdot \left[\frac{q_{ijk}}{t_{ijk}} - \frac{q_{ikl}}{t_{ikl}} \right] \right) \tag{4}$$

where

- c^{Ss}_{ik} is the specific storage cost of component i in warehouse k,
- q_{ikl} is the order amount of component i of user l from warehouse k,
- t_{ikl} is the delivery frequency of component i from warehouse k to user l.

As the objective function is available, the next step is to define the conditions to be taken into account in optimization. The following conditions should be taken into consideration:

$$q_{ijk\,\min} \le q_{ijk} \le q_{ijk\,\max} \tag{5}$$

$$q_{ikl\,\min} \le q_{ikl} \le q_{ikl\,\max} \tag{6}$$

$$t_{ik\,\min} \le t_{ik} \tag{7}$$

The first and second conditions express that delivery lot has to be between the delivery lot limits specified for the supplier. According to the third condition the time of delivery rate must exceed the minimum time of delivery rate offered by the supplier.

With the help of the objective function and condition equations outlined it is possible to define the time and amount of the order of the raw materials to be ordered from the suppliers, and with the help of these data deliveries to the storage places and to users can be scheduled and the relationship of components, suppliers, warehouses and users (structure of warehouses).

With the help of the method outlined it is possible to specify the control algorithms of the purchasing processes and the optimization process supporting the solution of the tasks to be completed.

4. Consequences

The just in time supply system is generally a multi-stage, multi-user system. The optimisation of this system is a very important task, because of time high cost rate of the design and operation of the system. Within the frame of this paper the author described a simple model of multi-stage, multi-user just in time supply, within the frame of which more intermediate warehouses are used to store the purchased components between the level of suppliers and users. The optimisation of this intermediate warehouse network is an important task of the design of the whole supply chain (number and structure of the intermediate warehouses). This paper summarises a simple mathematical model, which includes the most important aspects from the point of view logistics. The above mentioned mathematical model is based on a cost function including purchasing, transportation and warehousing costs. The optimisation problem can be solved by the aid of different heuristic methods, e.g. genetic algorithm, ant colony algorithm, harmony search etc.

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