

# Minimizing the Supply Chain Lead Time for a Hazardous Chemical Products in a VMI Environment

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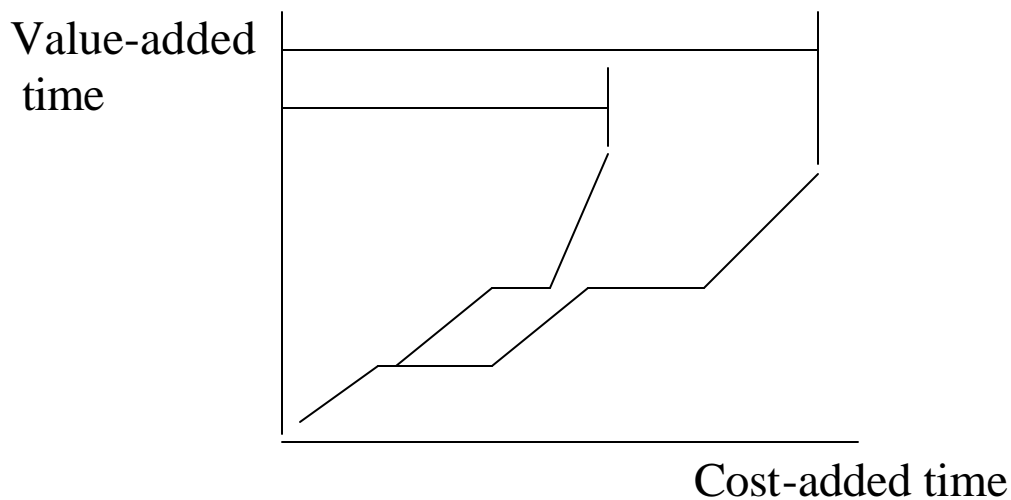
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## Background

- . The **supplier** for many contracted customers in chemical industries
- . Supplier's products: various organic peroxides for customers that produce: high molecular polymers, resin, rubber materials, paints, coating, and fibers
- . The main product: the initiator of Polyvinyl Chloride (PVC) polymerization process
- . The product starts to degrade whenever the storage temperature goes above 23F° or the time in storage goes beyond 2 months
- . Disposal of degraded product is extremely difficult due to the explosive nature
- . The products are essentially made to order
- . The costs associated with either customer waiting or product waiting are very high

# Supply Chain Initiatives

1. Long term: reduce the cash-to-cash cycle
  - *Reducing the length of the pipeline*



2. Short term: reduce the demand-to-delivery cycle

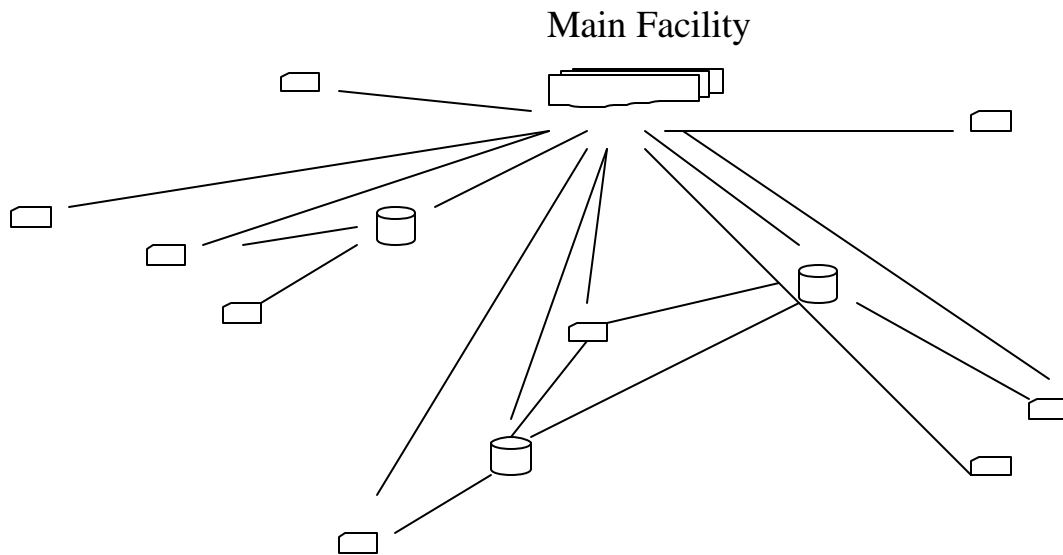
- *Order communication*
- *Order processing*
- *Production*
- *Transportation and delivery*

Promising a date then missing the delivery on-time is worse than promising a later date and delivering on-time.

----- **Accuracy in quote**

----- **Lean time management**

# Factors for the **lead time management**

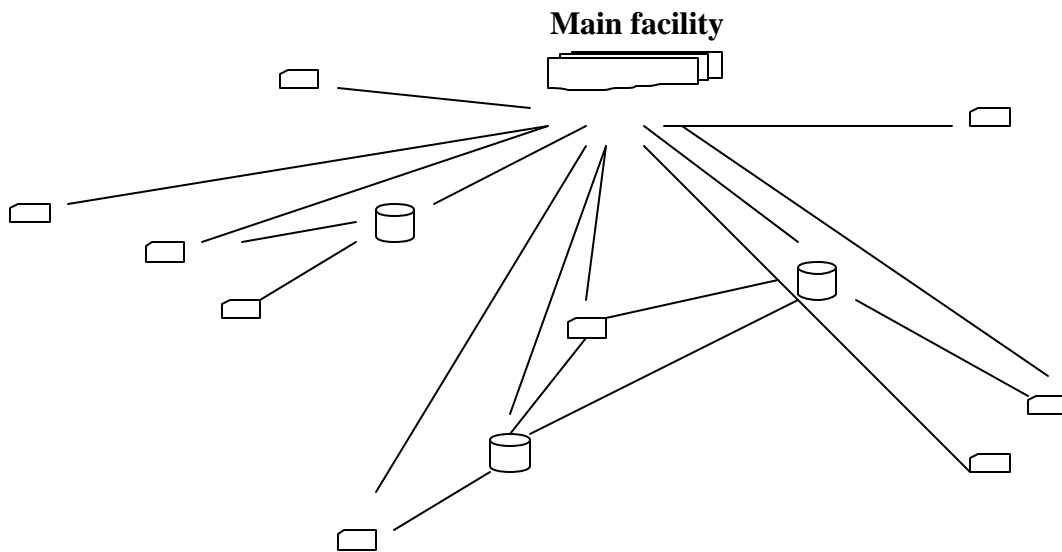


- . Some customer orders involve a customization processing at supplier's facility. The customization takes time.
- . The delivery of products to customers is not instantaneous, and requires the use of special (refrigerated) trucks.
- . The time gap between the product being produced and then being used in customers' production process must be as short as possible.

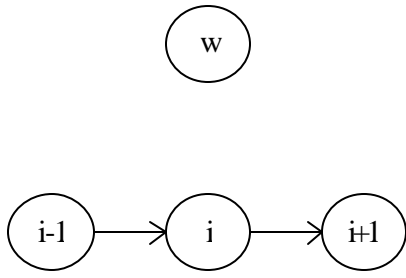
---- **Motivation to a VMI process**

**Major issues to be addressed:**

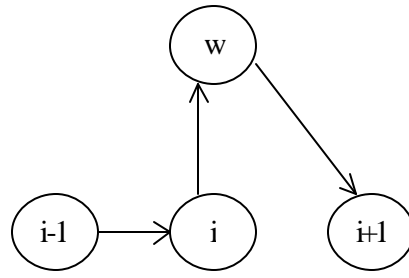
- . Strategic locations of processing facilities for customization (based on customers' strategic plan and competitors' strategic plans).
- . Combined routing and inventory decisions on various products and distribution consolidation
- . Routing decisions when multi-stage customization needs to be considered



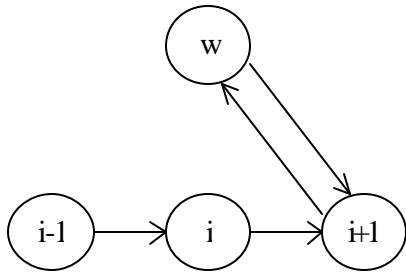
**(a)**



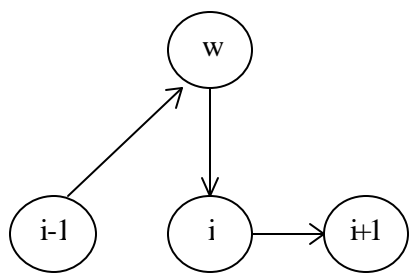
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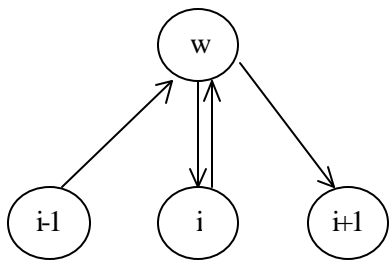
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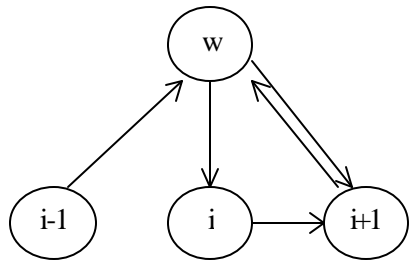
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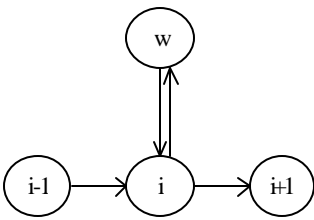
**(e)**



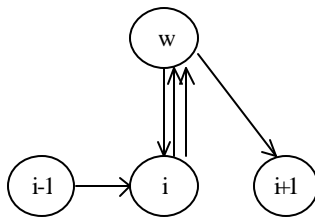
**(f)**



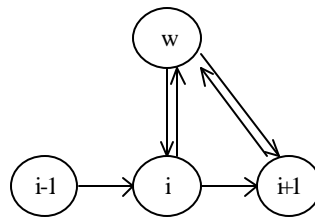
**(g)**



**(h)**



**(i)**



# **#1 Single capacitated vehicle routing for a hazardous product (i.e., the initiator for PVC) in a VMI environment**

Given:

- A single refrigerated vehicle with capacity  $C$
- A set of  $N$  customer locations, each with  $Q_i$ , some of them require customization process
- The location of supplier's main facility  $W$
- A set of locations of supplier's processing facilities (and the availability of facilities)

$P_0$ : How to come up with a quick, accurate and cost-effective plan for delivery ?

$P$ : How to determine the route of the vehicle so that the capacity constraint and all the customer requirements are satisfied, and the total time to make the delivery is minimized ?

The resulting schedule will provide important information for estimating the lead time for each customer order and consequently for coordinating the production schedule of customers

**P1:** If the sequence in which N customers will be visited is fixed, how to determine the route ?

$$\min T(R) = T_N + t_{N,w}$$

*s.t.*

$$T_i \geq T_{i-1} + w_{i-1,i} (t_{i-1,w} + t_{w,i}) + (1 - w_{i-1,i}) t_{i-1,i} + 2w_{i,i} t_{w,i}$$

$$L_i = (w_{i-1,i} + w_{i,i})C + (1 - w_{i-1,i})L_{i-1} - d_i$$

$$0 \leq w_{i-1,i} + w_{i,i} \leq 1$$

$$(L_{i-1} - d_i)w_{i,i} \leq 0$$

$$w_{i-1,i}, w_{i,i} = \text{binary}$$

$$T_i, L_i \geq 0$$

for all  $i=2, \dots, N$

$$T_k \geq T_j + p_{j,k}$$

for all (j, k) pairs

$$T_1 = t_{1,w}$$

$$L_1 = C - d_1$$



## A heuristic algorithm for P1

$$\{ S = \langle (l_w, 0), (l_1, Q_1), (l_2, Q_2), \dots, (l_N, Q_N) \rangle, C \}$$

1. Formulate and solve the shortest path problem. Call each node on the shortest path a potential node.

$$(i) \text{-----} (i+1) \text{-----} (i+2) \text{-----} (i+3) \text{-----} \dots \text{---}$$

2. For each potential node  $i$ , determine the maximum delivery scope  $\langle l_{i+1}, l_{i+2}, \dots, l_{i+m} \rangle$ . If the delivery to  $l_{i+m}$  is split, then let the vehicle capacity leaving  $l_{i+m}$  be

$$C' = 2C - \sum_{k=i+1 \dots i+m} Q_k$$

and solve the shortest path problem for the remaining nodes. Let

$$x_i = G_0 - G_i \quad \text{as the potential of node } i$$

3. Choose the route associated to node  $i^*$

$$x_{i^*} = \max. \{ x_i = G_0 - G_i \mid \text{for all potential } i \}$$

## A Heuristic solution procedure for P

1: Initialization. Let  $I$  be the set of all customer sites  $s_i$ , and

$$G(i, j) = \begin{cases} t_{w,i} + t_{i,j} + t_{j,w} & \text{if } d_i + d_j \leq C \\ t_{w,i} + t_{i,w} + t_{w,j} + t_{j,w} & \text{if } d_i + d_j > C \end{cases}$$

$$Z = \infty$$

2: Iteration. Solve the Assignment ( $\|I\|$ ) problem with

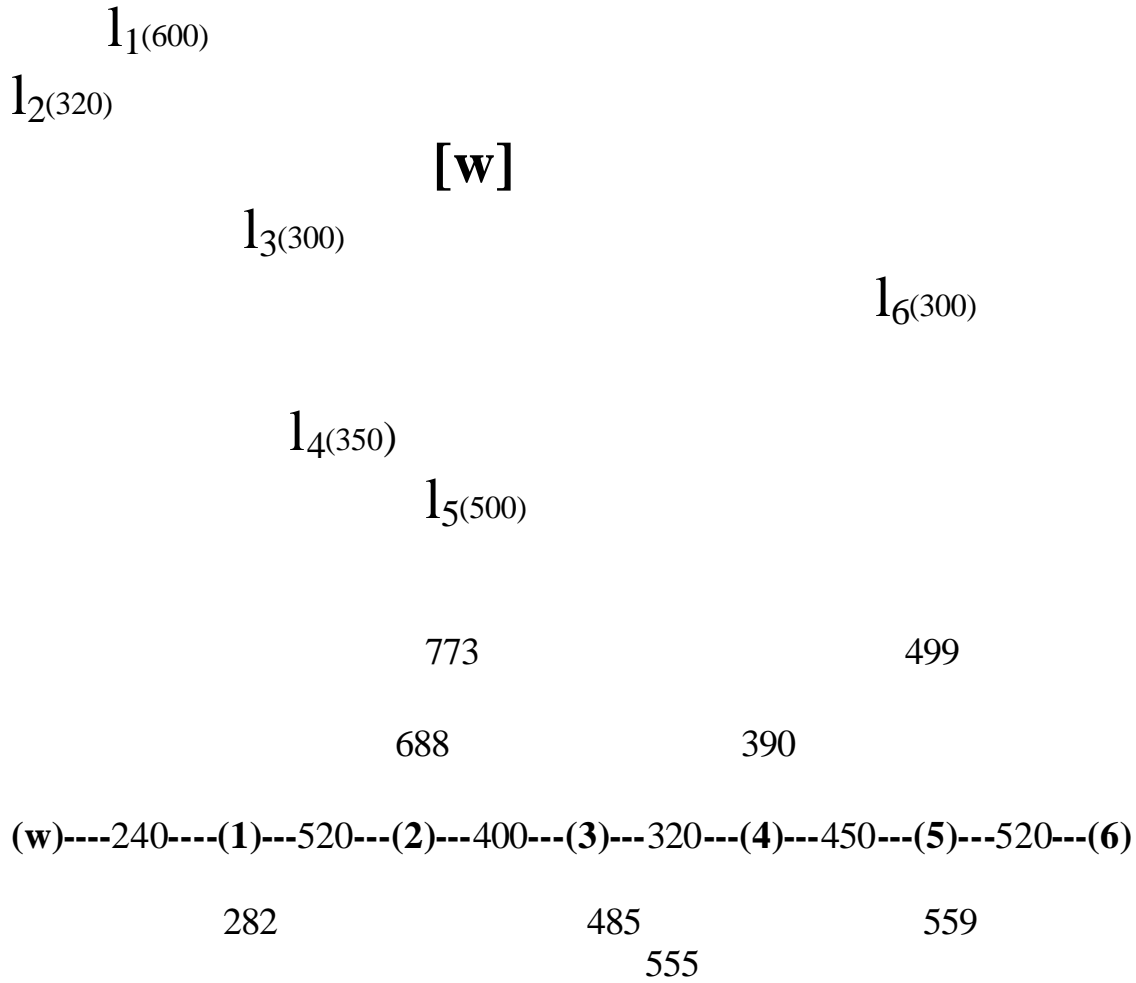
$$a_{ij} = \begin{cases} G(\text{subroute } i, \text{subroute } j) & \text{if } i \neq j \\ Z & \text{otherwise} \end{cases}$$

Return with objective value  $Z'$  and set of subroutes  $I'$ .

3: Check if  $\|I'\| = 1$ . If not, let  $I = I'$ ,  $Z = Z'$  and go to step 2; otherwise, let  $R$  be the resulting route and go to step 4.

4: Pick  $j \in S_2$ . Let  $S_2 = S_2 - \{j\}$ , determine the optimal insertion position of  $j$  in  $R$ . Let  $R = \arg\min T(R)$ .

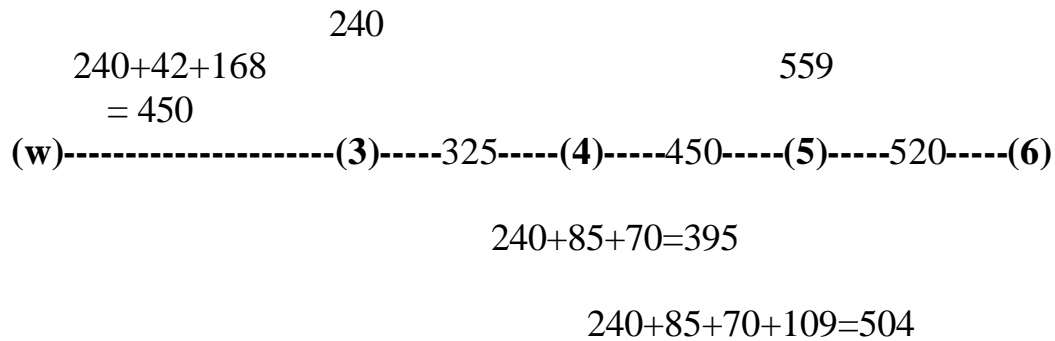
5: Check if  $\|S_2\| = 0$ . If not, go to step 4; otherwise, let  $R^* = R$  and stop.



$$G_0 = 1181$$

With Potential node W:

$$C' = 1200 - 20 = 1180$$



$$G_1 = 954 \quad \text{Saving of } 227$$

# Remaining Work

1. Error bound analysis for the heuristic algorithm for  $P_1$ ;
2. Consolidation delivery plans when multiple products are involved;
3. Consolidation delivery plans when the capacity of the main facility is not infinite;
4. Routing and scheduling when customers have preferred delivery time and whenever the actual delivery time deviates from the preferred time, a penalty occurs;
5. Multi-stage customization.