Logistic service scheduling

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Abstract

Reasonable scheduling of logistics service supply chain is essential. To minimize the total cost of the service, minimize the difference between the total service time and the customers; requirement and maximize the satisfaction, we established two scheduling models with fixed customer order decoupling point(CODP). One model ignores the relationship between the time window of supplier operation and the customer requirement and focus on the cost and satisfaction, while the other one considering the relationship. We convert the multiple-objective programming model into a LP problem and solve it with Cplex.

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1 Introduction

Nowadays logistics enterprises provide mass customization logistics services(MCLS) which allows customer to request customization service or mass service. To provide better service, the logistics service integrator need to reduce the cost, satisfy the customers' time requirement and keep functional logistic service providers satisfied. Our report focus on the schedule model in the two-echelon logistic service supply chain. This paper is organized as follows. In **section 2**, we introduce our schedule model regarding the problem. In **section 3**, we analyze the problem and the algorithm to solve the problem. In **section 4**, we analyze the time complexity of the algorithm and evaluate the performance of our model with the given data. The reference section and acknowledge section are given respectively at the end.

2 Model building

2.1 Problem describing

Assume there is a two-echelon logistics service supply chain(LSSC) with one logistics service integrator(LSI) and many functional logistic service providers(FLSP). The LSI may receive many orders from customers at a time. Each order consists of multiple service processes, which can be divided into two types, the customized service process and the mass service process. The service process of customers is conducted either being integrated into the mass service process or being operated independently as customized service. The LSI analyses the demand from customer and inquires the FLSPs of each service process about the time window for completing the service process.Then the LSI needs to schedule the orders and determine which process are conducted in mass mode and which are in customized mode.For example, there are three customers: Then the LSI would

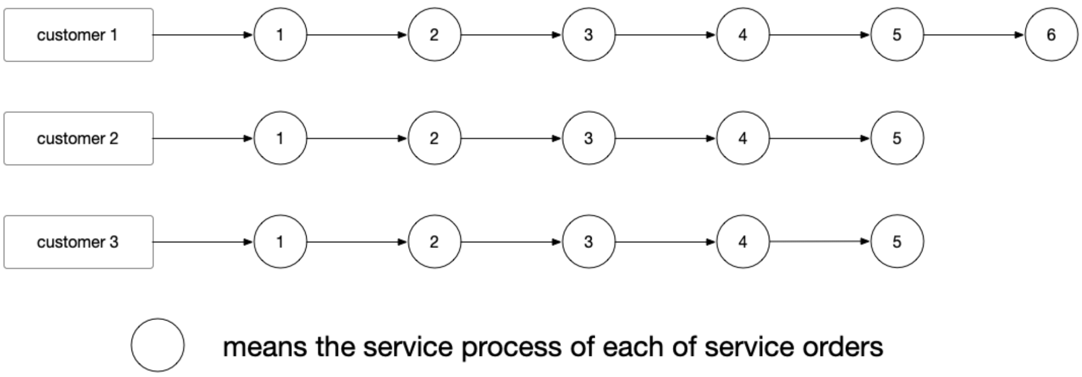

Figure 1: Example of customer requeset

determine the CODP and execute some of the processes in mass service and others in customized service. Our goal is schedule the processes and met the goals.

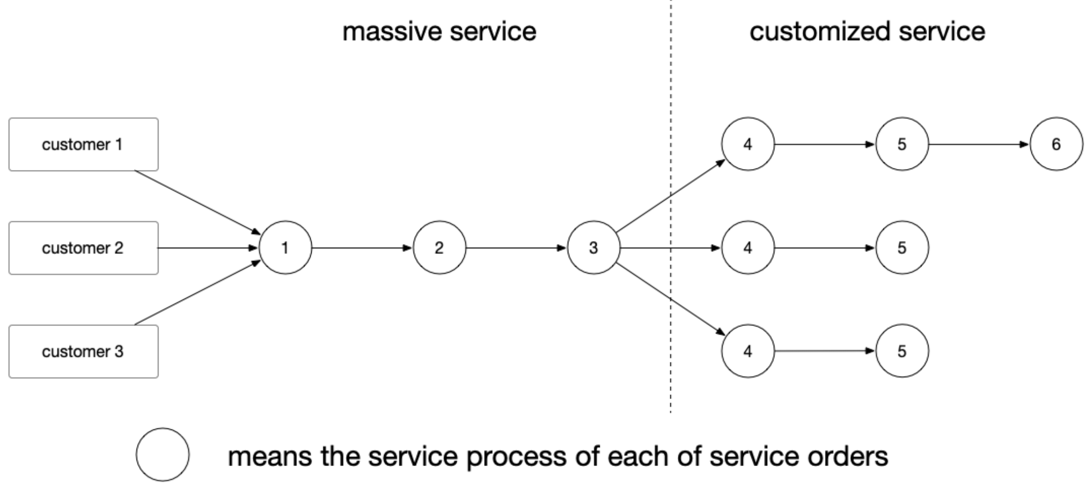

Figure 2: Demonstration of the actual service

2.2 Notation

The notation of the model are as follows:

Notation	Description
T_i^{exp}	The expect time for FLSP to complete ith process in offering mass service
T_i	The actual time FLSP takes to complete ith process in offering mass service
T_i^{ext}	The time LSI scheduled for ith process in mass service
T_{ij}^{exp}	The expect time for FLSP to complete ith process in customized mode for customer j
T_{ij}	The actual time FLSP takes to complete ith process in customized mode for customer j
T_{ij}^{ext}	The time LSI scheduled for customer j in ith process
T_j^{exp}	The custmoer j's expected completion time
T_{i+1}^{+}	In mass processes, the upper limit of the time delay incurred in the (i 1)th service process which could be endured by the ith service process. It is determined by the rigid requirement caused by upstream and downstream operations of LSSC.
T_{i+1}^{-}	In mass processes, the upper limit of the time ahead of schedule incurred in the (i 1)th service process which could be endured by the ith service process, which is determined by the rigid requirement caused by upstream and downstream operations of LSSC.

$T^{+}_{(i+1)j}$	In customized processes, for the jth customer order, the upper limit of the time delay incurred in the (i 1)th service process which could be endured by the ith service process, which is determined by the rigid requirement caused by upstream and downstream operations of LSSC.
$T^{-}_{(i+1)j}$	In customized processes, for the jth customer order, the upper limit of the time ahead of schedule incurred in the (i 1)th service process which could be endured by the ith service process, which is determined by the rigid requirement caused by upstream and downstream operations of LSSC.
C_i	The normal cost per unit time of ith process in offering mass service
C_i^{ext}	The extra cost per unit time of ith process in offering mass service
C_{ij}	The normal cost per unit time of ith process in offering customized service for customer j
C_{ij}^{ext}	The extra cost per unit time of ith process in offering customized service for customer j
P_i	The penalty per unit time of ith process in mass service if order is finished ahead of the expected time
P_{ij}	The penalty per unit time of ith process in customized service for customer j if order is finished ahead of the expected time
U_i	The lower limit of the satisfaction degree of the ith mass process.
U_{ij}	The lower limit of the satisfaction degree of the ith customized process of the jth customer order.
Z_1	The total cost
Z_2	The satisfaction
Z_3	The closeness degree of the actual order completion time and its customer requirement.
k	Before kth process the service is mass and after it will be customized
Y	The total number of orders
Y_j	The number of orders from jth customer
c	The cost coefficient
β	The requirement coefficient
I_j	The number of processes in jth customer's order
J_0	The number of customers

Table 1: notation of the model

2.3 Assumption

According to the description we have following assumptions:

1. Each scheduling task aims at only one set of customer orders and no new orders are added

2. In terms of time scheduling, additional service costs are incurred.

3. The normal service time refers to the usual time needed in completing a task using FLSP capability. When the work is done in the expect time, the satisfaction of the FLSPs is the highest.

4. We assume that logistics service capacities in each process are adequate and thus there is not any capacities constraint.

2.4 Model Building

2.4.1 The model without the Relationship between Time Windows of Supplier Operation and Customer Requirement

In the problem, the object is to reduce the cost Z_1 and increase the satisfaction Z_2. We calculate the cost Z_1 as follows:

$$Z_1 = f_1 + f_2 + f_3 \tag{1}$$

where

$$f_1 = \sum_{i=1}^{i=k-1} (T_i C_i + |T_i^{ext}| C_i^{ext}) \times Y \tag{2}$$

$$f_2 = \sum_{i=k}^{I_j} \sum_{j=1}^{J_0} (T_{ij} C_{ij} + |T_{ij}^{ext}| C_{ij}^{ext}) \times Y_j \tag{3}$$

$$f_3 = \sum_{i=1}^{i=k-1} |(T_i^{exp} - T_i - T_i^{ext})| P_i \times Y + \sum_{i=k}^{I_j} \sum_{j=1}^{J_0} |(T_{ij}^{exp} - T_{ij} - T_{ij}^{ext})| P_{ij} \times Y_j \tag{4}$$

f_1 is the cost of mass service and f_2 is the cost of customized service. f_3 is the penalty.
We define the satisfaction Z_2 via the relationship between the expected time and the actual time and the relationship between the cost of normal service and the total cost[1]:

$$\begin{aligned} Z_2 = (&\sum_{i=1}^{i=k-1} (1 - |\frac{T_i^{exp} - T_i}{T_i^{exp}}|)(\frac{T_i C_i}{T_i C_i + T_i^{ext} C_i^{ext}}) + \sum_{i=k}^{I_j} \sum_{j=1}^{J_0} (1 - |\frac{T_{ij}^{exp} - T_{ij}}{T_{ij}^{exp}}|)(\frac{T_{ij} C_{ij}}{T_{ij} C_{ij} + T_{ij}^{ext} C_{ij}^{ext}})) \\ &\times (k - 1 + \sum_{j=1}^{J_0} (I_j - (k-1)))^{-1} \end{aligned} \tag{5}$$

As for restraints:

$$T_{i+1}^{-} \leq T_i^{exp} - T_i - T_i^{ext} \leq T_{i+1}^{+} \quad , i \leq k-1 \tag{6}$$

$$T_{(i+1)j}^{-} \leq T_{ij}^{exp} - T_{ij} - T_{ij}^{ext} \leq T_{(i+1)j}^{+} \quad , i > k \tag{7}$$

$$(1 - |\frac{T_i^{exp} - T_i}{T_i^{exp}}|)(\frac{T_i C_i}{T_i C_i + |T_i^{ext}| C_i^{ext}}) \geq U_i \tag{8}$$

$$(1 - |\frac{T_{ij}^{exp} - T_{ij}}{T_{ij}^{exp}}|)(\frac{T_{ij} C_{ij}}{T_{ij} C_{ij} + T_{ij}^{ext} C_{ij}^{ext}}) \geq U_{ij} \tag{9}$$

Because $Z_2 \in \{0,1\}$.Simplify the multiobjective programming model, We get:

$$\begin{aligned}
\min \quad & K_1 Z_1 + K_2 Z_1^{min}(1 - Z_2) && (10)\\
\text{s.t.} \quad & T_{i+1}^{-} \le T_i^{exp} - T_i - T_i^{ext} \le T_{i+1}^{+} \quad , i \le k-1 && (11)\\
& T_{(i+1)j}^{-} \le T_{ij}^{exp} - T_{ij} - T_{ij}^{ext} \le T_{(i+1)j}^{+} \quad , i \ge k && (12)\\
& (1 - |\frac{T_i^{exp} - T_i}{T_i^{exp}}|)(\frac{T_i C_i}{T_i C_i + |T_i^{ext}| C_i^{ext}}) \ge U_i && (13)\\
& (1 - |\frac{T_{ij}^{exp} - T_{ij}}{T_{ij}^{exp}}|)(\frac{T_{ij} C_{ij}}{T_{ij} C_{ij} + |T_{ij}^{ext}| C_{ij}^{ext}}) \ge U_{ij} && (14)\\
& && (15)
\end{aligned}$$

K_1 and K_2 represents the weight of Z_1 and Z_2.

2.4.2 The model with the Relationship between Time Windows of Supplier Operation and Customer Requirement

Considering the relationship between time windows of supplier operation and customer requirement, we introduce a new variable Z_3 to describe the closeness of the actual order completion time and its customer requirement.

$$Z_3 = \sum_{j=1}^{J_0} |\frac{T_j^{exp} - T_j}{T_j^{exp}}| \times \frac{Y_j}{Y} \tag{16}$$

where

$$T_j = \sum_{i=1}^{I_j} (T_i + T_i^{ext} + T_{ij} + T_{ij}^{ext}) \tag{17}$$

T_j is the actual time to complete customer$j$'s order.
Hence, there are three objects. To simplify the multiobjective programming model, we restrain Z_1 to

$$Z_1 \le Z_1^{min} \times (1 + c) \tag{18}$$

where c is the cost coefficient and

$$Z_1^{min} = \sum_{i=1}^{i=k-1} T_i C_i \times Y + \sum_{i=k}^{I_j} \sum_{j=1}^{J_0} (T_{ij} C_{ij}) \times Y_j \tag{19}$$

Considering the requirement of the customer we also add a constraint of the time required by customers: $T_j \le T_j^{exp}(1+\beta)$. Then we got:

$$\begin{aligned}
\min \quad & K_3 Z_3 + K_2(1 - Z_2) && (20)\\
\text{s.t.} \quad & T_j \le T_j^{exp}(1+\beta) && (21)\\
& T_{i+1}^{-} \le T_i^{exp} - T_i - T_i^{ext} \le T_{i+1}^{+} \quad , i \le k-1 && (22)\\
& T_{(i+1)j}^{-} \le T_{ij}^{exp} - T_{ij} - T_{ij}^{ext} \le T_{(i+1)j}^{+} \quad , i \ge k && (23)\\
& (1 - |\frac{T_i^{exp} - T_i}{T_i^{exp}}|)(\frac{T_i C_i}{T_i C_i + T_i^{ext} C_i^{ext}}) \ge U_i && (24)\\
& (1 - |\frac{T_{ij}^{exp} - T_{ij}}{T_{ij}^{exp}}|)(\frac{T_{ij} C_{ij}}{T_{ij} C_{ij} + T_{ij}^{ext} C_{ij}^{ext}}) \ge U_{ij} && (25)\\
& Z_1 \le Z_{1min} && (26)
\end{aligned}$$

convert it into LP:

$$
\begin{aligned}
\min \quad & K_3 Z_3 + K_2(1 - Z_2) && (27)\\
\text{s.t.} \quad & T_j \leq T_j^{exp}(1+\beta) && (28)\\
& T_{i+1}^{-} \leq T_i^{exp} - T_i - T_i^{ext} \leq T_{i+1}^{+} \quad , i \leq k-1 && (29)\\
& T_{(i+1)j}^{-} \leq T_{ij}^{exp} - T_{ij} - T_{ij}^{ext} \leq T_{(i+1)j}^{+} \quad , i \geq k && (30)\\
& (1 - |\frac{T_i^{exp} - T_i}{T_i^{exp}}|)^{-1}(1 + \frac{T_i^{ext} C_i^{ext}}{T_i C_i}) \leq U_i^{-1} && (31)\\
& (1 - |\frac{T_{ij}^{exp} - T_{ij}}{T_{ij}^{exp}}|)^{-1}(\frac{T_{ij}^{ext} C_{ij}^{ext}}{T_{ij} C_{ij}}) \leq U_{ij}^{-1} && (32)\\
& Z_1 \leq Z_{1min} && (33)
\end{aligned}
$$

K_2 and K_3 represents the weight of Z_2 and Z_3

3 Problem Analysis and Algorithm Design

Our defined problem is a multiple-objective programming problem. We simplify the problem with linear weight method and get the synthesized objective function. Our single-objective model could be converted into LP. Hence the defined problem should be in P and we could use various algorithms to solve the problem. Using Ellipsoid Method the time complexity would be $O(n^6 L^2)$ where n is the dimension of variables and L is the length of input. If we solve the problem using Interior-Point Method the time complexity would be $O(n^{3.5} L^2)$.
For example, Barrier Method[2]:

Algorithm 1: Barrier Method

```
given strictly feasible
while True do
    Centering step. Compute by minimizing, subject to, starting at.
    Update.
    Stopping criterion. quit if.
    increase.
```

In this project we use Cplex to solve the LP problem.

4 Theoretical Analysis and Performance Evaluation

4.1 Theoretical Analysis

The time complexity is determined by the method we use to solve the LP problem. If we use simplex method, the time complexity is $O(2^n)$. If we use Ellipsoid Method the time complexity would be $O(n^6L^2)$. If we use Interior-Point Method, the time complexity would be $O(n^{3.5}L^2)$. We use Cplex to solve the LP problem.

4.2 Performance Evaluation

4.2.1 Evaluation of the model without the Relationship between Time Windows of Supplier Operation and Customer Requirement

For service time distribution, we generate the actual service time via a random function. The data we use are listed as follows:

The result is showed in the figures:

4.2.2 Evaluation of the model with the Relationship between Time Windows of Supplier Operation and Customer Requirement

In this model we have two coefficients c and β.

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References

[1] Liu WH, Yang Y, Li X, Xu HT, Xie D. A time scheduling model of logistics service supply chain with mass customized logistics service. Discrete Dynamics in Nature and Society. 2012;2012:18 pages.482978

[2] Stephen Boyd,Lieven Vandenberghe. Convex Optimization [M]