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Modeling integrated flow shop Scheduling problem and air transportation in supply chain

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Abstract

The lack of coordinated and efficient production planning and air transportation is a challenge for world-class companies and causes obstacles to their development process in creating a collaborative environment and being more competitive. Thus, the need to establish a unified coordinated model to produce a realistic plan with regard to production and distribution in the supply chain is felt. For this purpose, mathematical programming model taking into account the preparation time depends on sequences of production are offered in order to minimize the total cost of the supply chain including distribution costs, earliness and tardiness of production and delivery.

Keywords: Scheduling, flow shop, supply chain, integration

Introduction

In decades of 60 and 70 BC, organizations in order to increase their competitiveness and improve their internal processes attempted to produce standardized products with better quality and lower cost of production. At that time, the dominant thinking was that strong engineering and design, as well as integrated production operations are prerequisites for access to the market demands and therefore having more market share. That's why organizations put all their efforts on improving the efficiency. In the 80s with increasing diversity in the expected patterns of customers, organizations were interested increasingly to increase flexibility in production lines and develop new products to satisfy the needs of customers. In the 90s, along with improvements in manufacturing processes and use of patterns of re-engineering, managers of many industries found that in order to stay on the market only improving internal processes and flexibility in the company's capabilities is not enough, but suppliers of components and materials must produce materials with best quality and lowest cost and distributors of products should also have a close relationship with manufacturers market development policies. With such attitudes, approaches of supply chain and their management puts it into existence. On the other hand, with the rapid development of information technology in recent years and its widespread use in supply chain management, most of the supply chain management fundamental activities are being performed with new ways.

Supply Chain Management describes the delivery of goods, services and sends information at the right time, right place and high quality. Designing a network of transportation in the supply chain, is one of the most fundamental decisions in supply chain management that has a great impact on return of investment and overall performance of the chain. The main components of the supply chain are customers and need them. The main objective of supply chain management system is to minimize costs while meeting the needs of customers.

Supply chains studies are shown in Figure 1. In this chain, components are stored as inventory. Upon reaching a customer order, components and products which are required are being transferred to the production line and products are being delivered by using air transport to achieve their customers in deliverables due. Coordination of production and air transportation is important, because the shipments that are losing their scheduled flight must be transported by special flights and they are incurred heavy costs. In this study, additional costs related to specific flights is called a late penalty of flights take off. Earliness costs are due to the need to store orders in the factory or the expected and keeping cost of the airport. Penalties for delay occurs when an order arrives late or early to clients. The cost of late delivery are including of customer dissatisfaction, fines of contract, loss of sales, loss of dachas or loss of reputation for the manufacturer and retailer. If time of arrival (ETA) allocated in the airlift orders are delivered prematurely, retailers have delivered in the earliness. Hence, the cost of earliness in delivery of orders is considered by retailers as the cost of storage.

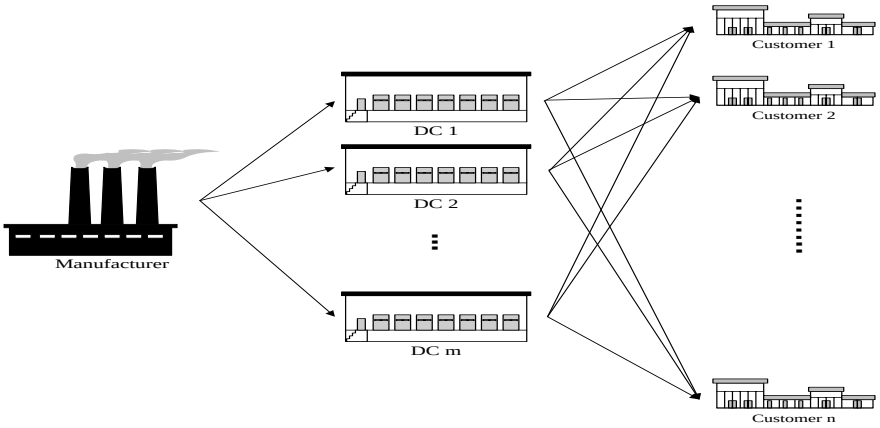

Figure 1 is scheduling the flow shop and integrated air transport

Theoretical basis of research:

Scheduling flow shop problem is one of scheduling models in production environments. During the production lines in flow shop, there are *m* machines or work centers that have been set in sequences and all the works are processed on these machines according to the same processing sequence. The processing time for each job can be different on each machine. It is assumed that all the works in the zero time are available and are being set in the same direction flow.

Coordinated supply chain scheduling problem is one of the hardest combinatorial optimization problems. This issue is important in two researchable aspects of production management and operations and combinatorial optimization and in recent years has attracted the attention of many researchers. Research

in this field is based on the type of vehicles in the distribution sector and is divided into two categories: transport (on road or a vehicle) and cargo aircraft (air transport).

Research Background

Most researches reported in the supply chain are related to strategy and tactics to optimize the structure and management system in consistence with economic goals. (Blumenfeld et al (1991), Chen (2005), Li et al (2007), Sarmiento and Naji (1999), Govetschaleks et al (2002), Jafarzadeh, H. et al., (2017). More attention has been to the coordination of production and distribution in operation timing, (Fumero, F. and Vercellis (1999) and Chang (2004). Soukhal and et al (2005) have shown great potential to reduce costs to coordinate decisions in the supply chain (Elyasi M.et al., 2012a, 2012b).

Because of emerging newly coordinated scheduling with production and air transportation problem, there are very little researches on this topic. Li et al (2005) were the first scholars who question scheduling synchronization of a single machine and air carriers with one destination. The whole question was into two issues of single-machine scheduling problem and air transportation is divided. They have formulated the problem and then provided a heuristic algorithm for scheduling single machine backward. Lee and colleagues (2005) have expanded their own work by taking several air freights. Wang et al (2007) have showed that the allocation of air transport structure is regular transportation issues, while the problem was single-machine scheduling problem NP-Hard (non-polynomial hard). They have also proposed innovative way forward and backward innovative methods for single machines . Li and colleagues (2005) have developed their work with regard to parallel machines in production. They issued the problem as parallel machines with the earliness penalties of flights and showed the non-polynomial parallel machine scheduling problem is complete and offered a heuristic algorithm based on simulated annealing for parallel machines (Jafarzadeh, H. et al., 2014). They compared the simulated annealing algorithm with a method of manufacturing operations in Singapore. Zandie and Mullah Ali Zadeh Zavardehi (2008) have provided mathematical programming models by taking virtual delivery strategy of delay allowance and non- allowance delay. Zandie and Mullah Ali Zadeh Zavardehi (2009) have developed their mathematical programming models with regard to different capacities to carry their development. Rostamian Delaware and colleagues (2010) have provided a meta-heuristic method based on genetic algorithm for scheduling integrated production and air transportation problem in a single machine (Hasani et al., 2013;Moradinasab, N., 2018).

wang et al (2005) in order to minimize the total cost of supply chain has provided an integrated model and resolved with algorithm of colonial rivalry to set the parameters of Taguchi experimental design and the effectiveness of the proposed algorithm has been evaluated with the genetic algorithm. Finally, by using the numerical experiments, the proposed algorithm output has the replying quality and satisfactory performance.

The used symbols in mathematical models of this research are as follows:

i, i', j :Indicator of order or work $i = 1, 2, ..., N;$

f , f' : Indicator of flight $f = 1, 2, ..., F;$

k :Destination Indicator $k = 1, 2, ..., K;$

t : Indicator of type of flight capacity $t = 1, 2, ..., T;$

p : Position or frequency of order i $p = 1, 2, ..., N;$

Input parameters include the following:

D_f : F flight departure time at the local airport

A_f : F flight arrival time at the destination

des_f : Destination f

Q_i The amount of order i

p_i Time of Order i

α_i The cost of earliness penalty in delivery (h / unit) of order i

β_i The cost of late delivery penalties (h / unit) of Order i

α'_i : Earliness penalty of order i for each time or work of i for production

β'_i :Transportation cost per unit of order i when is carried with an especial flight

d_i : delivery date of Order i

e_i : The earliest possible time for delivery of Order i

l_i : The latest possible time for delivery of order i

Des_i : Destination of order i

$NCap_f$: The normal capacity of flight f

$SCap_f$:Specific f flight capacity

Cap_{tf} :t : the T type of available capacity of flight f so that $t = 1, 2, ..., T$; $f = 1, 2, ..., F$;

NC_f : Shipping costs per unit of product, when normal flight capacity is allocated f

SC_f : Shipping costs per unit of product, when certain capacity of flight f is allocated

Tc_{tf} : Transportation cost of each unit of product when the capacity of t type is assigned for flight f

MD_i : The maximum specific flight time for order i to deliver all the orders on time

MDE_i :The maximum specific flight time for order i to deliver it in time

MDL_i : The maximum specific flight time for order i that can deliver the order late

λ :Cost of per hour of workshop (which includes the cost of machinery, wages and other different costs that are depending on the duration of production time)

$\overline{Cap}_{(T+1)i}$: Q_i If i order can be shipped with specific flight, 0 otherwise

$\bar{d}_i$: Immediate Delivery of order i (time of delivery where delay is allowed)

$\overline{MD}_i$: The maximum time that an specific flight of order i can deliver immediately,

$\bar{l}_i$: LN : If for i order delivery is delay allowed, otherwise d_i

$\overline{MDL_i}$: LN ، : If for i order delivery is delay allowed, otherwise MD_i

θ :A number between zero and one $0 < \theta < 1;$

LN :A large number of positive

Without losing of generality, it is assumed that. $D_1 \le D_2 \le ... \le D_F$.

3-1-5- decision variables

The decision variables used in the proposed mathematical model is as follows:

X_{if} : The part of the order i that has allocated the normal flight f capacity

Y_{if} : The part of the order i that has allocated particular flight f capacity

q_{tif} :The allocated amount of order i to capacity type of t in the flight f

$q_{(T+1)i}$:The allocated amount of order I to specified flight

u_{ip} : If the order i is in position p , 0 otherwise

c_i : Time to complete the order or work i

I_i : Idle time before order i in the timing

$C_{\max}$: The maximum time to complete the order, which is the time of closure of the workshop

3.2 Coordinated production Scheduling and air transportation

The whole question related is divided to two correlated and coordinated tasks in each case. The first task is considered the allocation of orders to available capacity on flights to minimize the total shipping costs of earliness and tardiness penalties in delivery in accordance with the terms and policies. At this stage, the allocation is limited to production, so that the allocation should be balanced with production capacity in all circumstances and policies. The timing and manufacturing is determined according to the results of the allocation of order.

Assignment problem in air freight delivery in delay allowed mood, with specific flight

With these assumptions, the objective function, the total cost of transportation is including the cost of specific flights and earliness and tardiness penalties capacity of delivery orders is allocated to minimize the first type of capacity to T of flights. The objective function of earliness and tardiness penalties of specific flights are not included because the start of trip depends on the time of completion of orders; because we don't consider specific flights in this model.

$$\text{Min} \sum_{t=1}^{T}\sum_{i=1}^{N}\sum_{f=1}^{F} Tc_{tf} q_{tif} + \sum_{t=1}^{T}\sum_{i=1}^{N}\sum_{f=1}^{F} \alpha_i * \max\left(0, d_i - A_f\right) * q_{tif}$$
$$+ \sum_{t=1}^{T}\sum_{i=1}^{N}\sum_{f=1}^{F} \beta_i * \max\left(0, A_f - d\right) * q_{tif} + \sum_{i=1}^{N} \beta_i' * q_{(T+1)i} \qquad (1)$$

s.t:

$$\sum_{t=1}^{T}\sum_{f=1}^{F} q_{tif} + q_{(T+1)i} = Q_i \qquad i = 1,2,...,N \tag{2}$$

$$\sum_{i=1}^{N}\left(\left(\frac{\max\left(0,\left(\sum_{t=1}^{T}\sum_{f'=1}^{f} q_{tif'}\right)-\theta\right)}{\left(\sum_{t=1}^{T}\sum_{f'=1}^{f} q_{tif'}\right)-\theta}\right)+\left(\left(1-\left(\frac{\max\left(0,\left(\sum_{t=1}^{T}\sum_{f'=1}^{f} q_{tif'}\right)-\theta\right)}{\left(\sum_{t=1}^{T}\sum_{f'=1}^{f} q_{tif'}\right)-\theta}\right)\right)\right.\right.$$

$$\left.\left.\left(\frac{\max\left(0,q_{(T+1)i}-\theta\right)}{q_{(T+1)i}-\theta}\right)\left(\frac{\min\left(0,MD_i-D_f-\frac{1}{LN}\right)}{MD_i-D_f-\frac{1}{LN}}\right)\right)\right) p_i \le D_f \qquad f = 1,2,...,F \tag{4}$$

$$\sum_{i'=1}^{i}\left(1-\left(\frac{\max\left(0,\left(\sum_{t=1}^{T}\sum_{f=1}^{F}\left(\frac{\min\left(0,D_f-MD_i-\frac{1}{LN}\right)}{D_f-MD_i-\frac{1}{LN}}\right)q_{ti'f}\right)-\theta\right)}{\left(\sum_{t=1}^{T}\sum_{f=1}^{F}\left(\frac{\min\left(0,D_f-MD_i-\frac{1}{LN}\right)}{D_f-MD_i-\frac{1}{LN}}\right)q_{ti'f}\right)-\theta}\right)\right)\left(\frac{\max\left(0,q_{(T+1)i}-\theta\right)}{q_{(T+1)i}-\theta}\right)p_{i'} +$$

$$\sum_{i'=1}^{N}\left(\frac{\max\left(0,\left(\sum_{t=1}^{T}\sum_{f=1}^{F}\left(\frac{\min\left(0,D_f-MD_i-\frac{1}{LN}\right)}{D_f-MD_i-\frac{1}{LN}}\right)q_{ti'f}\right)-\theta\right)}{\left(\sum_{t=1}^{T}\sum_{f=1}^{F}\left(\frac{\min\left(0,D_f-MD_i-\frac{1}{LN}\right)}{D_f-MD_i-\frac{1}{LN}}\right)q_{ti'f}\right)-\theta}\right)p_{i'} \le MD_i \quad i = 1,2,...,N$$

$$q_{(T+1)i} = \textit{Non-negative integer variable} \tag{5}$$

MD_i Is equal to scheduled flight time to carry order i with specific flight. Also, without loss of generality, we assume that orders are numbered in order of increase MD so that $MD_1 \le MD_2 \le ... \le MD_N$

The total cost of the main problem is equal to the objective function of above model and scheduled transportation cost of specific flights is in the air transport allocation model as follows:

$$\text{The total cost} = \sum_{t=1}^{T}\sum_{i=1}^{N}\sum_{f=1}^{F}\left(\left(\left(\frac{\min\left(0, c_i - D_f - \frac{1}{LN}\right)}{c_i - D_f - \frac{1}{LN}}\right)\left(\left(Tc_{tf} * q_{tif}\right) + \left(\alpha_i' * \left(D_f - c_i\right) * q_{tif}\right)\right.\right.\right.$$

$$\left.\left.\left. + \left(\left(\alpha_i * \max\left(0, d_i - A_f\right) * q_{tif}\right) + \left(\beta_i * \max\left(0, A_f - d_i\right) * q_{tif}\right)\right)\right)\right)$$

$$+\left(\left(1 - \left(\frac{\min\left(0, c_i - D_f - \frac{1}{LN}\right)}{c_i - D_f - \frac{1}{LN}}\right)\right)\left(\left(\beta_i' * q_{tif}\right) + \left(\min\left(\alpha_i', \alpha_i\right) * \max\left(0, MD_i - c_i\right) * q_{tif}\right)\right.\right.$$

$$\left.\left. + \left(\beta_i * \max\left(0, c_i - MD_i\right) * q_{tif}\right)\right)\right) + \sum_{i=1}^{N}\left(\left(\beta_i' * q_{(T+1)i}\right)\right.$$

$$\left. + \left(\min\left(\alpha_i', \alpha_i\right) * \max\left(0, MD_i - c\right) * q_{(T+1)i}\right) + \left(\beta_i * \max\left(0, c_i - MD_i\right) * q_{(T+1)i}\right)\right) + \lambda C_{\max} \quad (6)$$

To test the accuracy of the proposed models, a common small problem with the software of Lingo 8 is solved on all models. In one case with 2 order $(N = 2)$ with separate objectives 1 and 2 ($Des_1 = 1$) and $(Des_2 = 2$) in which each order can be shipped with 2 flight and different departure times($f = 4$), $T = 2$, $des_1 = 2$, $des_2 = 1$, $des_3 = 1$, $(des_4 = 2$). Other parameters in this example are as follows:

Table 1: parameters of orders

i	Des_i	Q_i	P_i	d_i	α_i	β_i
1	1	10	2	11	2	4
2	2	8	2	12	3	5

Table 2: parameters related to Flights

f	des_f	D_f	A_f	Cap_{1f}	Cap_{2f}	Tc_{1f}	Tc_{2f}
1	2	3	4	3	7	5	7
2	1	5	6.5	4	10	3	5
3	1	7	8.5	5	0	4	0
4	2	12	13	2	6	4	5

Other parameters are as follows:

$\beta'_1 = 8$, $\beta'_2 = 10$, $MD_1 = 10$, $MD_2 = 11$.

Responses indicate that order 1 is fully allocated to its specific flight ($q_{31} = 10$) and the allocated amount to specific flight is related to the order 2 equal to 6 ($q_{32} = 6$). Also the other results are shown in Table 3.

Table 3: results of the air freight mode in virtual delivery delay allowed mood, with specific flight

	$f=1$		$f=2$		$f=3$		$f=4$	
i	q_{1i1}	q_{2i1}	q_{1i2}	q_{2i2}	q_{1i3}	q_{2i3}	q_{1i4}	q_{2i4}
1	0	0	0	0	5	0	0	0
2	0	0	0	0	0	0	2	0

Conclusion

In this paper, we studied the coordination of the supply chain. A model was presented with various restrictions. The numerical model was run using Lingo software. Since there are a little research on coordination of air transportation and production planning in the supply chain, several studies can be done for the development of the subject. This research could by changes in the assumptions on production planning and cargo transportation type be reviewed or the impact of accidental allocation of processing time, sudden transportation of products and so on be added to first mathematical models, in addition, meta heuristic algorithms can be provided to solve the proposed model according to configured suit of production, such as single machine, parallel machine, flow shop, job shop, and more.

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Appendix

Lingo Code:

```
model:
sets:
job/1..2/:d,Des,a,P,Q,q3,b,MD,ko,ac,EF,b1;
JOB2/1..2/;
flight/1..4/:D2,des2,A2,tc1,tc2,cap1,cap2;
flight2/1..4/;
links1(job,flight):q1,q2,a3,pa2,h,EF1;
endsets
data:
a=2 3 ,b=4 5.b1=8 10,d=11 12,MD=10 11,p=2 2,Q=10 8,Des=1 2,D2=3 5 7 12,des2=2 1 1 2,A2=4 6.5 8.5 13;
cap1=3 4 5 2,cap2=7 10 0 6,tc1=5 3 4 4,tc2=7 5 0 5,ko=.001 .001;
enddata
min=@sum(job(i):@sum(flight(f):(((tc1(f)*q1(i,f))+(tc2(f)*q2(i,f)))+(a(i)*
(q1(i,f)+q2(i,f))*@smax(0,(d(i)-A2(f))))+(b(i)*(q1(i,f)+q2(i,f))*
@smax(0,(A2(f)-d(i)))))))+@sum(job(i):(b1(i)*q3(i)));
@for(job(i):@for(flight(f):((q1(i,f)+q2(i,f))*(Des(i)-des2(f)))=0));
@for(flight(f):(@sum(job(i):q1(i,f)))<=cap1(f));
@for(flight(f):(@sum(job(i):q2(i,f)))<=cap2(f));
@for(job(i):(@sum(flight(f):(q1(i,f)+q2(i,f))))+q3(i)=Q(i));
@for(flight(f):(@sum(job(i):(pa2(i,f)+((1-pa2(i,f))*ac(i)*EF1(i,f)))*p(i)))<=D2(f));
@for(job(i):@for(flight(f):(@sum(flight2(f2)|f2#LE#f:(q1(i,f2)+(q2(i,f2)))))=
h(i,f)));
@for(job(i):@for(flight(f):(@smax(0,(h(i,f)-0.5)))/(h(i,f)-0.5)=pa2(i,f)));
@for(job(i):((@smax(0,(q3(i)-0.5)))/(q3(i)-0.5))=ac(i));
@for(job(i):@for(flight(f):((@smin(0,(MD(i)-D2(f)-ko(i))))/(MD(i)-D2(f)-ko(i)))=EF1(i,f)));
@for(job(i):@sum(job2(i2):(EF(i2)*p(i2)))+@sum(job2(i2)|i2#LE#i:((1-EF(i2))*
ac(i2)*p(i2)))<=MD(i));
@for(job(i):EF(i)=(@smax(0,((@sum(flight(f):EF1(i,f)*(q1(i,f)+
q2(i,f))))-0.5)))/((@sum(flight(f):EF1(i,f)*(q1(i,f)+q2(i,f))))-0.5));
@for(job(i):@for(flight(f):@Gin(q1(i,f))));
@for(job(i):@for(flight(f):@Gin(q2(i,f))));
@for(job(i):@Gin(q3(i)));
end
```