A Resource Scheduling for Supply Chain Model

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Abstract

This paper presents an optimization formulation for resource scheduling in Critical Resource Diagramming (CRD) of production scheduling networks. A CRD network schedules units of resources against points of needs in a production network rather than the conventional approach of scheduling tasks against resource availability. This resource scheduling approach provides more effective tracking of utilization of production resources as they are assigned or "moved" from one point of need to another. Using CRD, criticality indices can be developed for resource types in a way similar to the criticality of activities in Critical Path Method (CPM). In our supply chain model, upstreams may choose either normal operation or expedited operation in resource scheduling. Their decisions affect downstream's resource scheduling. The suggested optimization formulation models resources as CRD elements in a production two-stage supply to minimize the total operation cost

1. Introduction

We will introduce a resource scheduling methodology for two stage supply chain model with multi-upstreams that produce their own parts. When we consider two upstreams and one downstream, the upstream A produces the part A and the upstream B produce the part B and the downstream need both the part A and B to assemble. We assume that inventory control policy in supply chain environment is same as the Huggins and Olsen's model (2003). They considered a problem where the downstream facility's supply requests are always met by the upstream facility. If the downstream facility orders more than the upstream facility has on hand, the upstream facility must meet the shortage by expediting. Such expediting often consists of either overtime production or premium freight. Overtime production builds the required parts at the end of the day, at a higher cost than regular production. Premium freight ships, for example, by airplane with a higher shipping cost. Each upstream can optimize its own resource scheduling. But, the schedules of each upstream affect the schedule of downstream. We need to consider the resource scheduling in supply chain. Our main research object is to develop the resource scheduling model in the two stage supply chain model with multiple upstream.

2. Problem

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In this problem, the planning horizon is consisted with the overtime production period and the regular production period. And the decision point is the end of regular production period. At the decision point, the downstream requests the parts to each upstreams. The each upstream can ship non-expedited parts (NEP) that are already stored in inventory by regular freight and the part can arrive at downstream before the next regular production horizon. If shortage occurs, upstream has to expedite production or shipping to make expedited part. The upstream can produce expedited parts (EP) during either the overtime period or the next regular production period. And they can ship the parts by either the premium freight or the regular freight. Both premium freight and regular freight can be used at any time.

At the upstream, there are two kinds of expediting decision factor and one kind of shipping decision factor for non-expedite parts. First, they have to decide either overtime production or regular production. Second, they have to decide either premium freight or regular shipping. Another decision factor is shipping for the non-expedited part. The upstream can wait and ship the non-expedited part with expedited part, or ship the non-expedited part immediately without waiting the expedited part. So each upstream has three decision factors that have two options and it means there are all eight combinations of options. And upstream has to produce parts for its own inventory, but overtime cost can be added depending on scheduled time.

When we optimize the total cost of for the upstreams and downstream, the mathematical formulation is introduced as mixed integer programming formulation. MRSSC(Multiple Resource Scheduling for Supply Chain)

$$Min\sum_{j}\{C_{\mathrm{Pr}_j} \times \mathrm{Pr}_j + C_{\mathrm{P}oj} \times \mathrm{P}o_j + C_{Fr_j} \times Fr_j + C_{Fpj} \times Fp_j$$
$$+C_{\mathrm{Im}_j} \times \mathrm{Im}_j + C_{IwFpj} \times IwFp_j + C_{IwFrj} \times IwFr_j + COU_j \times TOU_j$$
$$+C_{Pj}\} + \sum_{k}\{C_{A_k} + COD \times TOD_{A_k}\}$$

Subject to

$$(ST_{Frj} + T_{Frj}) \le PE_j + M \times (1 - Fr_j), \forall j$$
$$(ST_{Fpj} + T_{Fpj}) \le PE_j + M \times (1 - Fp_j), \forall j$$
$$(ST_{\mathrm{Im}_j} + T_{\mathrm{Im}_j}) \le PI_j + M \times (1 - \mathrm{Im}_j), \forall j$$
$$(ST_{\mathrm{I}wFrj} + T_{\mathrm{I}wFrj}) \le PI_j + M \times (1 - \mathrm{I}\,wFr_j), \forall j$$
$$(ST_{\mathrm{I}wFpj} + T_{\mathrm{I}wFpj}) \le PI_j + M \times (1 - \mathrm{I}\,wFp_j), \forall j$$
$$(ST_{Frj} + T_{Frj}) \le ST_{IwFrj} + M \times (1 - Fr_j), \forall j$$
$$(ST_{Fpj} + T_{Fpj}) \le ST_{IwFpj} + M \times (1 - Fp_j), \forall j$$
$$(ST_{\mathrm{Pr}_j} + T_{\mathrm{Pr}_j}) \le ST_{Frj} + M \times (1 - \mathrm{Pr}_j), \forall j$$
$$(ST_{Poj} + T_{Poj}) \le ST_{Frj} + M \times (1 - Po_j), \forall j$$
$$(ST_{\mathrm{Pr}_j} + T_{\mathrm{Pr}_j}) \le ST_{Fpj} + M \times (1 - \mathrm{Pr}_j), \forall j$$
$$(ST_{Poj} + T_{Poj}) \le ST_{Fpj} + M \times (1 - Po_j), \forall j$$
$$(ST_{\mathrm{Pr}_j} + T_{\mathrm{Pr}_j}) \le ST_{Pj} + M \times (1 - \mathrm{Pr}_j), \forall j$$
$$(ST_{\mathrm{P}oj} + T_{\mathrm{P}oj}) \le ST_{Pj} + M \times (1 - \mathrm{P}o_j), \forall j$$
$$ST_N + T_N \le ST_{Pj}, \forall j$$

$ST_{N} + T_{N} \le ST_{Pr_j}, \forall j$

$ST_{N} + T_{N} \le ST_{A}$

$PI_j \le ST_{A_1}, \forall j$

$PE_j \le ST_{A_k}, k = PA_j, \forall j$

$ST_{A_{k-1}} + T_{A_{k-1}} \le ST_{A_k}, k = 2, \mathrm{L}\ , K$

$ST_{P_j} + T_{P_j} - TOU_j + TSU_j = ERT, \forall j$

$ST_{A_k} + T_{A_k} - TOD_{A_k} + TSD_{A_k} = ERT, \forall k$

$\Pr_j + Po_j = 1, \forall j$

$Fr_j + Fp_j = 1, \forall j$

$\mathrm{Im}_j + IwFr_j + IwFp_j = 1, \forall j$

$IwFr_j \le Fr_j, \forall j$

$IwFp_j \le Fp_j, \forall j$

$\Pr_j, Po_j, Fr_j, Fp_j, \mathrm{Im}_j, Iw_j = 0 \text{ or } 1\ , \forall j$

When each upstream optimizes only its local cost without considering the downstream scheduling, the upstream minimize its production cost and transportation cost.

3. Numerical example

We have two upstreams and one downstream. We can calculate the required quantity of parts. Downstream requests 700 parts, but upstream 1 has only 400 on hand inventory and needs 300 expedited parts and 800 parts for next period. And upstream 2 has only 300 on hand inventory and needs 400 expedited parts and 600 parts for next period.

	Down	UP 1	UP 2
On Hand Inventory	500	400	300
Required Inventory position	1200	800	600
Expedited	0	300	400
Regular	700	800	600
Total required	700	1100	1000

The costs for the operations are given as following table;

	Option	FC	VC	FT	VT
Upstream	Overtime	1000	2	30	0.5
	Regular	1000	1	30	0.5
Shipping	Premium	500	3	180	0
	Regular	300	1	480	0
Downstream	Overtime	1000	2	30	0.5
	Regular	1000	1	30	0.5

(FC is Fixed cost, VC is variable cost, FT is fixed time and VT is variable time per item.)

Our problem can be solved by CPLEX. If each upstream optimize its own local cost, then the local optimal combination of options of upstream 1 is (Pr1,Fr1,IwFr1) and its cost is 4240, and upstream2 has local optimal options (Pr2,Fr2,IwFr2) and its cost is 4040. In this upstream resource scheduling, downstream scheduling is behind due time. The downstream assembly cost is 2460 including overtime cost 760. The total cost is 10740. But, if we optimize global cost, then the optimal combination of operation of upstreaml is (Pol, Frl, IwFrl) and its cost is 4400, and those of upstream are (Po2, Fr2, IwFr2) and 4400. Each cost of upstream in global optimization is more expensive than that of local optimization. But, downstream scheduling is finished before the due time. And the downstream assembly cost is 1700. The total cost is 10500 which is cheaper than that of local optimization.

5. Conclusion

This paper has illustrated how the basic CRD methodology of scheduling project resources can be adapted for a supply chain problem in production planning and scheduling. Other scheduling scenarios can be addressed by the basic idea of resource-based network analysis. As the mathematical formulation becomes more complex, more ingenious solution techniques will need to be developed. Such alternate solution techniques could include neural networks (Senouci and Adeli, 2001), genetic algorithms (Chan et al. 1996; Yang 2000, 2001), or resource-activity path planning (Lu and Li, 2003).

Reference

[1] Badiru, Adedeji B. 1992. Critical Resource Diagram: A New Tool for Resource Management, *Industrial Engineering* 24(10) 58-59.

[2] Badiru, Adedeji B.1993. Activity-Resource Assignments Using Critical Resource Diagramming, *Project Management Journal* 24(3) 15-21.

[3] Badiru, Adedeji B.1995. Incorporating Learning Curve Effects into Critical Resource Diagramming, *Project Management Journal* 26(2) 38-45.

[4] Chan, Weng-Tat; David K. H. Chua; and Govindan Kannan. 1996. Construction Resource Scheduling With Genetic Algorithms, *Journal of Construction Engineering and Management*, 125-132.

[5] Huggins, Eric Logan and Tava Lennon Olsen. 2003. Supply Chain Management with Guaranteed Delivery, *Management Science* 49(9) 1154-1167.

[6] Lu, Ming and Heng Li. 2003. Resource-Activity Critical-Path Method for Construction, *Journal of Construction Engineering and Management*. 412-420.

[7] Senouci, Ahmed B. and Hojjat Adeli. 2001. Resource Scheduling Using Neural Dynamics Model of Adeli and Park, *Journal of Construction Engineering and Management* 28-34.

[8] Yang, Byounghak 2000. Development of a Package for the Multi-Location Problem by Genetic Algorithm, *IE Interface* 13(3).

[9] Yang, Byounghak. 2001. Developing a Genetic Algorithm for the Rectilinear Steiner Tree Problem, *Korean Journal of logistics* 9(2).