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RESEARCH MEMORANDUM

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A MODIFIED PRIORITY INDEX FOR GÜNTHER'S LOT-SIZING HEURISTIC UNDER CAPACITATED SINGLE STAGE PRODUCTION

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A modified priority index for Günther's lot-sizing heuristic under capacitated single stage production

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Abstract: This paper suggests a modification of Günther's lot-sizing heuristic for capacitated single stage production that may yield better results in terms of overall cost performance. The computational efficiency of the heuristic allows both versions to be incorporated in the decision making process, which is hereby improved. The performance of both versions of Günther's heuristic is compared in a number of test problems reflecting relatively stable and lumpy demand conditions, respectively.

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1. Introduction

Günther [2] recently developed a heuristic for capacity constrained lot-sizing for multiple products to be produced on a single production facility. Demand was assumed deterministic and time-varying without backordering, where setup times did not consume limited production capacity. The objective then is to determine lot-sizes which minimize the sum of inventory holding and setup costs, based on Groff's [1] lot-sizing criterion. Feasibility of the schedule is guaranteed by means of a capacity balancing rule, where portions of current slack capacity are reserved in order to balance future capacity overloads. As such it is possible that a particular requirement may be split into several lots when capacity constraints are binding. Günther uses a priority index for this capacity balancing by computing the incremental cost per unit of additional capacity absorbed, where cost is defined as the sum of additional holding and setup costs.
In computing this priority index, Günther states that "increasing the lot size of a particular product does not affect setup costs if the product is already scheduled in the current period". It is argued that this may not be the case when an entire future period requirement is added to the existing lot-size. The modified priority index that would result is discussed next.

2. Modified priority index

Relevant notation is briefly outlined below:

k : current period of production

$p(i)$: supply period for product i, defined as the next period with a positive requirement of product i

q_{ip} : maximum quantity of product i which can be shifted from period $p(i)$ to period k for pre-production

h_i : holding cost per unit and period for product i

S_i : setup cost for product i

x_{ik} : lot-size of product i in period k

$d(x_{ik})$: binary decision variable indicating whether product i is setup in period k or not, with $d(x_{ik}) = 1$ if $x_{ik} > 0$, zero otherwise

a_i : production time per unit for product i.

Günther computes the priority index for capacity balancing (denoted by v_i) as:

$$v_i = [(p(i) - k)\ q_{ip}h_i + S_i(1 - d(x_{ik}))]/(q_{ip}a_i) \tag{1}$$

The first part of this index indicates the additional holding cost of shifting q_{ip} requirements of product i from future period p(i) to the current period of production k. The second part stands for the additional setup cost incurred when product i is not currently being produced. The denominator normalizes this cost in terms of the incremental capacity used.

We note that in formula (1), when q_{ip} equals x_{ip} or an entire period requirement is shifted forward under the condition that product i is currently produced, the priority index yields:

$$v_i = [(p(i) - k)q_{ip}h_i]/(q_{ip}a_i) \tag{2}$$

However, for the above situation an additional setup is saved, in particular the one for period p(i). As the entire period requirement is added to a current lotsize, that period's setup is saved and is reflected in the following modified priority index:

$$v_i = [(p(i) - k)q_{ip}h_i + S_i(1 - d(x_{ik})) - S_i(1 - d(x_{ip},q_{ip}))]/(q_{ip}a_i) \tag{3}$$

where $d(x_{ip},q_{ip})$ is a binary decision variable indicating whether or not an entire period requirement of product i is shifted forward, with

$$d(x_{ip}, q_{ip}) = 1 \text{ if } x_{ip} > q_{ip}$$

$$= 0 \text{ if } x_{ip} = q_{ip}$$

Equation (3) is rewritten as:

$$v_i = [(p(i) - k)q_{ip}h_i + S_i(d(x_{ip}, q_{ip}) - d(x_{ik}))]/(q_{ip}a_i) \qquad (4)$$

Using this priority index, the possible contingency situations in terms of potential savings in setup costs, are summarized in Figure 1.

		Current period requirement x_{ik} $x_{ik} = 0$	$x_{ik} > 0$
	$x_{ip} > q_{ip}$	$v_i = [(p(i)-k)q_{ip}h_i + S_i]/(q_{ip}a_i)$ or one additional setup incurred	$v_i = [(p(i)-k)q_{ip}h_i]/(q_{ip}a_i)$ or no incremental setup cost savings
Future period requirement x_{ip}	$x_{ip} = q_{ip}$	$v_i = [(p(i)-k)q_{ip}h_i]/(q_{ip}a_i)$ or no incremental setup cost savings	$v_i = [(p(i)-k)q_{ip}h_i - S_i]/(q_{ip}a_i)$ or one setup saved

Figure 1. Possible contingency situations

3. Example problems

A turbo-PASCAL computer program of Günther's heuristic was developed, yielding two versions depending on which rule was used. These versions are denoted by "Günther" and "modified Günther", respectively.

A set of 10 randomly selected example problems were generated to illustrate the performance of both versions, based upon the following production setting as is illustrated in Table 1.

Table 1. Production Setting

Product	Production time (hours)	Holding cost/unit/period ($)	Setup cost ($)
1	0.12	5.2	268
2	0.15	4.5	321
3	0.20	5.4	380

A planning horizon of seven periods was chosen, with respective production capacities as are shown in Table 2.

Table 2. Production Capacities (hours)

Period	1	2	3	4	5	6	7
Capacity	25	25	10	10	10	10	10

The sample set of 10 problems consisted of 5 randomly chosen problems with relative stable demand, and five examples in which demand was lumpy, whereby total demand over the seven period planning horizon was held constant for all cases. The demand patterns for all cases are shown in Table 3, in which cases 6 through 10 reflect the lumpy demand pattern.
The resulting production schedules and relevant costs for both approaches are depicted in Tables 4 and 5 according to the demand structure.

Table 3. Demand - Example cases.

		Period							
Case	Product	1	2	3	4	5	6	7	Σ
1	1	46	40	55	48	46	40	60	335
	2	28	20	25	35	37	30	24	199
	3	10	8	12	7	9	7	8	61
2	1	42	44	50	53	42	48	56	335
	2	25	30	22	25	30	35	32	199
	3	10	9	11	8	7	8	8	61
3	1	40	44	50	55	47	49	50	335
	2	29	32	27	38	25	27	20	199
	3	10	10	9	7	10	8	7	61
4	1	60	55	48	40	46	46	40	335
	2	37	30	28	20	30	25	29	199
	3	7	7	12	10	8	9	8	61
5	1	47	50	52	54	48	46	38	335
	2	24	20	25	35	32	30	33	199
	3	12	10	7	10	8	9	5	61
6	1	80	70	80	20	30	20	35	335
	2	80	100	10	0	0	7	2	199
	3	9	0	0	5	0	27	20	61
7	1	30	20	29	31	110	80	35	335
	2	8	12	10	11	18	85	55	199
	3	1	8	5	4	4	23	16	61
8	1	90	10	83	20	30	32	70	335
	2	50	12	10	9	80	15	23	199
	3	6	16	5	20	4	5	5	61
9	1	60	60	60	28	35	30	62	335
	2	12	80	18	10	60	10	9	199
	3	20	8	10	5	4	0	14	61
10	1	5	100	0	130	80	20	0	335
	2	80	0	0	90	20	5	4	199
	3	2	0	7	2	0	30	20	61

Table 4. Production results - Günther (G) and Modified Günther (MG)
Stable Demand

Case	Product	Method	Production per period 1	2	3	4	5	6	7	Setup Cost	Holding Cost	Total Cost
	1	G	86	103	0	0	46	40	60	3764		
		MG	86	0	83.33	65.67	0	40	60	4085		
1	2	G	48	0	60	66.67	0	24.33	0		2106.20	
		MG	48	60	0	0	37	34.67	19.33		1592.03	
	3	G	37	0	0	0	16	0	8			5870.20
		MG	37	0	0	9	15	0	0			5677.03
	1	G	42	94	83.33	0	45	14.67	56	3652		
		MG	42	94	0	53	83.33	6.67	56	4032		
2	2	G	77	0	0	55	0	54.93	12.07		2008.70	
		MG	77	0	55	0	0	50.67	16.33		1725.33	
	3	G	38	0	0	0	23	0	0			5660.70
		MG	38	0	0	15	0	8	0			5757.33
	1	G	40	94	0	83.33	18.67	49	50	4353		
		MG	40	94	0	66.67	35.33	49	50	4733		
3	2	G	61	0	65	0	27.73	27.47	16.8		1056.83	
		MG	61	0	65	0	27.73	27.47	16.8		1024.17	
	3	G	36	0	0	0	18	0	7			5409.83
		MG	36	0	0	10	8	0	7			5757.17
	1	G	60	103	0	83.33	2.67	46	40	3973		
		MG	60	103	0	40	46	46	40	4353		
4	2	G	67	0	48	0	30	25	29		1164.33	
		MG	67	0	48	0	30	29.87	24.13		966.30	
	3	G	36	0	0	0	25	0	0			5137.33
		MG	36	0	0	17	0	0	8			5319.30
	1	G	47	102	0	83.33	18.67	46	38	4353		
		MG	47	102	0	54	48	46	38	4353		
5	2	G	44	0	66.67	0	29.07	29.87	29.4		1103.63	
		MG	44	0	66.67	0	28.27	29.87	30.2		1035.70	
	3	G	39	0	0	0	17	0	5			5456.63
		MG	39	0	0	17	0	0	5			5388.70

Table 5. Production results - Günther (G) and Modified Günther (MG).
Lumpy Demand

Case	Product	Method	Production per period 1	2	3	4	5	6	7	Setup Cost	Holding Cost	Total Cost
6	1	G	80	70	80	50	0	20	35	3711		
		MG				SAME				SAME		
	2	G	80	110	0	0	0	9	0		291	
		MG				SAME					SAME	
	3	G	14	0	0	0	0	27	20			4002
		MG				SAME						SAME
7	1	G	50	170	80	0	0	0	35	3116		
		MG	50	60	0	83.33	83.33	58.33	0	3764		
	2	G	41	0	0	0	66.67	66.67	24.67		4945.20	
		MG	41	103	0	0	0	20	35		4263.70	
	3	G	22	0	0	39	0	0	0			8061.20
		MG	22	0	23	0	0	0	16			8027.70
8	1	G	100	0	83	50	0	32	70	3764		
		MG				SAME				SAME		
	2	G	72	0	0	26.67	62.33	38	0		950.80	
		MG				SAME					SAME	
	3	G	6	50	0	0	0	0	5			4714.80
		MG				SAME						SAME
9	1	G	60	60	60	63	0	59.58	32.42	3652		
		MG	60	60	60	63	0	30	62	3652		
	2	G	12	108	0	0	60	19	0		865.93	
		MG				SAME					787.70	
	3	G	47	0	0	0	0	0	14			4517.93
		MG	47	0	0	0	0	14	0			4439.70
10	1	G	5	100	83.33	46.67	80	20	0	4032		
		MG	5	100	47.92	82.08	80	20	0	4032		
	2	G	80	86.67	0	28.33	0	0	4		1456.33	
		MG	80	86.67	28.33	0	0	0	4		1399.67	
	3	G	11	0	0	0	0	30	20			5488.33
		MG				SAME						5431.67

Interestingly, the better performance of the amended heuristic lies in the improvement in inventory holding costs over the potential worsening of setup costs. This is easily explained by the fact that the amended version employs a different decision rule (priority index) for shifting future requirements forward in time, yielding different production schedules as is shown in Tables 4 and 5. For the examples generated, in 7 out of 10 cases, the modified version outperformed or performed equally well as Günther's approach. However, it is important to note that, due to the different priority indices of either approach, the modified version is not always guaranteed to produce better results as compared to Günther's solutions. There exists an indication the amended version may perform better for lumpy demand conditions, allowing the decision maker to run both versions and select the better solution, moreover as Günther's heuristic proved to be computationally very efficient.

4. Conclusions

The priority rule for pre-production in Günther's lot-sizing heuristic was modified to correctly reflect the situation where an entire future period requirement is shifted to the current period of production. This modification subsequently yields a different production plan that may outperform Günther's heuristic solution, as was illustrated. The computational efficiency of the heuristic allows both versions to be incorporated in the decision making process, which is hereby improved.

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