Developing a Supply-Quantity Allocation Model for Production Planning with Common Parts

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Abstract: - In the complex supply chain system, to satisfy the manufacturer's various demands on parts, each supplier needs to lay an emphasis on its advantageous conditions. Especially, in cases of multi-products and many types of common parts, the cost weighing of suppliers will be the best benchmark for the company in the selection of proper suppliers. This study will first lay out various product parts by the Bill of Material (BOM) and construct a mathematical model suitable for the purchase cost, transport cost and assembly cost of multi-products with common parts to construct the selection structure for various suppliers. Moreover, the limited supplier production capacity, the optimized specific common parts suppliers' combinations and corresponding assigned quantities are worked out by Genetic Algorithm (GA). Further, it makes possible for current multi-products companies to have a benchmark in the selection in the future.

Key-Words: - Supply chain, Bill of material, Common part, Supplier selection, Genetic algorithm

1 Introduction

Whatever type of enterprise lays an emphasis on reducing production costs constantly to maximize its profits. Under the current extremely rapid changing market circumstances, such tenets are still the invariable aims. In addition, Wang and Che [1] believed that many present companies aim for improving and updating products in response to fiercely competitive commercial market. Therefore, in the production process, many production nodes are more interlinked. As far as purchase is concerned, it is a very important task prior to production. Huang [2] believed that an effective purchase department could continuously help the company reduce costs and increase profits. Then, the raw materials purchase has become a more important decision for the management in the simultaneous operation of multi-products operation as well as an important link in the company supply strategy. Therefore, how to get the fairly good quality, lowest cost and accurate quantity at proper time is a factor has to be considered when purchasing.

And Xu [3] believed that suppliers in the selection process can reduce parts prices or shorten lead time. Therefore, Rui and Joao [4] pointed out that the company has to consider taking more than two suppliers in case of high chance of changing pre-positive time to reduce the stock maintenance cost or stock depletion cost by dividing orders. Hence, Xia and Wu [5] believed that the right suppliers from selection can conspicuously reduce the raw materials purchase cost and improve the company competitiveness. This is the reason why many experts regard supplier selection as the most important activity of the purchase department. As above, this study will develop a mechanism for multi-products common parts suppliers' selection and supply quantity allocation. Moreover, Hokey et al. [6] believed it is the best heuristic algorithm based on population by making use of genetic algorithm and it can produce the single optimized solution as well as a group of optimized solutions. Therefore, we adopt GA to work out various parts suppliers with limited resources by making use of gene features (reproduction, crossover, and mutation) and the most accurate order allocation decision, which further maximizes the company profits as well as reduces unnecessary wastes, expanding them to many different industries.

2 Problem Description

The problem discussed in this study is to describe the supplier's order allocation of common parts in case of multi-products production and to allocate supply quantity to each supplier according to their capacities. When placing orders, customers usually take product as the quantity unit while a product is assembled from one or more parts. Therefore, the manufacturer has to calculate the total sum of parts needed according to the total demands of products. In the production process, parts purchase is the most fundamental and most important link of the whole production process. The multi-product parts suppliers selection process in this study mainly contains following points:

- Disintegrate the product by BOM, propose the final parts and work out the total demands of all parts needed.
- Find out the supplier with minimum cost according to the selection model and conduct purchase demand assignments and suppliers selection for these products.

This study is to solve the problem of determining which parts suppliers can meet the demand of lowest cost.

3 Model Development

The model in this study is constructed by following assumptions:

- The total sum of the maximum production capacities of various parts suppliers can all satisfy the total demands of various parts.
- No stock depletion in the orders of parts.
- Each supplier has its supply upper limit, that is, the production upper limit of each supplier, ordered quantity of the supplier cannot exceed the total sum of its production upper limit.
- The manufacturer considers purchase, assembly and transport cost only in purchasing. Therefore, with the different costs of different suppliers, we may have one or more suppliers.

The parameters used in the mathematical model are hereby listed as follows:

h	assembly hierarchy index, $h=1,2,3,...,H$
H	total number of hierarchy
n	module index, $n=1,2,3,..., N_h$
N_h	total number of modules in hierarchy h
p	product index, $p=1,2,3,...\ P_m$
P_m	total number of product
x, k	part index, $x=1,2,3,..., X_n$, $k=1,2,3,..., K_n$
y, ℓ	part-supplier indexes of part x and part k, $y=1,2,3,..., Y_x$, $\ell=1,2,3,..., L_k$
X_n, K_n	total number of parts in module n
Y_x, L_k	total number of suppliers in part x and part k
f_n^h	module n in hierarchy h
$C_p^{f_n^h}$	total cost under sequential module f_n^h in product p
$D_x^{f_n^h}$	part x under sequential module f_n^h
$D_{x,y}^{f_n^h}$	supplier y of part x under sequential module f_n^h
$D_{k,\ell}^{f_n^h}$	supplier ℓ of part k under sequential module f_n^h
$D_{x,y,k,\ell}^{f_n^h}$	supplier y of part x and supplier ℓ of part k under sequential module f_n^h
$AC_p^{D_{x,y,k,\ell}^{f_n^h}}$	assembly cost of supplier y of part x and supplier ℓ of part k under sequential module f_n^h in product p
$PC_p^{D_{x,y}^{f_n^h}}$	purchase cost of supplier y of part x under sequential module f_n^h in product p
$TC_p^{D_{x,y}^{f_n^h}}$	transport cost of supplier y of part x under sequential module f_n^h in product p
$AR_p^{D_{x,y,k,\ell}^{f_n^h}}$	$\begin{cases}1, \text{supplier } y \text{ of part } x \text{ has assembly relationship with supplier } \ell \text{ of part } k \text{ in product } p \\ 0, \text{otherwise}\end{cases}$
$S_p^{D_{x,y}^{f_n^h}}$	$\begin{cases}1, \text{supplier } y \text{ of part } x \text{ under sequential module } f_n^h \text{ is selected in product } p \\ 0, \text{otherwise}\end{cases}$
$S_p^{D_{k,\ell}^{f_n^h}}$	$\begin{cases}1, \text{supplier } \ell \text{ of part } k \text{ under sequential module } f_n^h \text{ is selected in product } p \\ 0, \text{otherwise}\end{cases}$
e	common part index, $e=1,2,3,...,E$
E	total number of common parts
DE_e	total demands of common part e
$Q_{x,k}$	assembly quantities of part x and part k
Q_x	quantity of part x
$RPC_p^{D_{x,y}^{f_n^h}}$	purchase budget cost upper limit of part x supplied by supplier y under each sequential modules in product p
$RTC_p^{D_{x,y}^{f_n^h}}$	transport budget cost upper limit of part x supplied by supplier y under each sequential modules in product p
$V_{x,y}$	maximum production capacity of part x supplied by supplier y
j	common part supplier index, $j=1,2,3,...,J$
J	total number of common part suppliers
$\delta_{p,e,j}$	maximum production capacity of supplier j of common part e in product p
θ_x	$\begin{cases}1, x \text{ part is selected repeatedly} \\ 0, \text{otherwise}\end{cases}$
$\lambda_{p,x,y}$	production quantity of part x of the supplier y selected for product p

The mathematical module of this study is as follows:

$$Minimize\ F(c) = \sum_{p=1}^{P_m} \sum_{n=1}^{N_h} C_p^{f_n^h} \tag{1}$$

$$C_p^{f_n^f} = \sum_{x=1}^{X_n} \sum_{y=1}^{Y_x} \sum_{k=1}^{K_n} \sum_{\ell=1}^{L_k} AC_p^{D_{x,y,k,\ell}^{f_n^h}} \cdot AR_p^{D_{x,y,k,\ell}^{f_n^h}} \cdot S_p^{D_{x,y}^{f_n^h}} \cdot S_p^{D_{k,\ell}^{f_n^h}} \cdot Q_{x,k} + \sum_{x=1}^{X_n} \sum_{y=1}^{Y_x} PC_p^{D_{x,y}^{f_n^h}} \cdot S_p^{D_{x,y}^{f_n^h}} \cdot \theta_x \cdot Q_x + \sum_{x=1}^{X_n} \sum_{y=1}^{Y_x} TC_p^{D_{x,y}^{f_n^h}} \cdot S_p^{D_{x,y}^{f_n^h}} \cdot \theta_x \cdot Q_x \tag{2}$$

s.t

$$PC_p^{D_{x,y}^{f_n^h}} \le RPC_p^{D_{x,y}^{f_n^h}}, \quad for \quad all\ x, y, h, n, p \tag{3}$$

$$TC_p^{D_{x,y}^{f_n^h}} \le RTC_p^{D_{x,y}^{f_n^h}}, \quad for \quad all\ x, y, h, n, p \tag{4}$$

$$\sum_{p=1}^{P_m} \sum_{j=1}^{J} \delta_{e,p,j} \ge DE_e, \quad for \quad all\ e, p, j \tag{5}$$

$$\sum_{p=1}^{P_m} \lambda_{p,x,y} \le V_{x,y}, \quad for \quad all\ x, y, p \tag{6}$$

$$\lambda_{p,x,y} \ge 0, \quad for \quad all\ x, y, p \tag{7}$$

Objective Equation (1) is to calculate the total cost of all products including purchase, transport and assembly costs in between various parts. Equation (2) is the main cost function of this model and the cost calculation equation for various products. Restricting Equation (3) means the purchase cost of each part must less than the purchase budget cost upper limit. Equation (4) refers to the transport cost of each part shall be less than the transport budget cost upper limit. Equation (5) represents the sum of each common part suppliers' capacity must satisfy the total demand of various common parts. Equation (6) refers to all the demands of all the parts must be less than the maximum capacity of suppliers under limited supplier production capacity. Equation (7) determines that the ordered quantity of each part supplier shall be a positive integral. This research adopts GA to find out the optimized supplier combination and the supply quantities of various suppliers in steps as stated below:

Step 1: According to practical product requirements, get requested assembly parts from BOM table and add up demands of same materials to work out the total demands for individual parts.

Step 2: According to the capacity limits of various suppliers, work out the production quantities of all available suppliers of various parts by the net demands of various parts.

Step 3: The chromosome structure in this study is as shown in Fig. 1. The supply quantity supplied by the supplier is determined by real number codes. The initial solutions are generated according to the capacity of various suppliers. Input the chromosome into fitness function and add purchase cost, transport cost, and assembly cost as well as capacity limit to serve as the operational procedure of the most appropriate value.

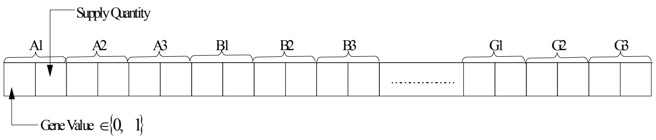


Fig. 1 Chromosome structure

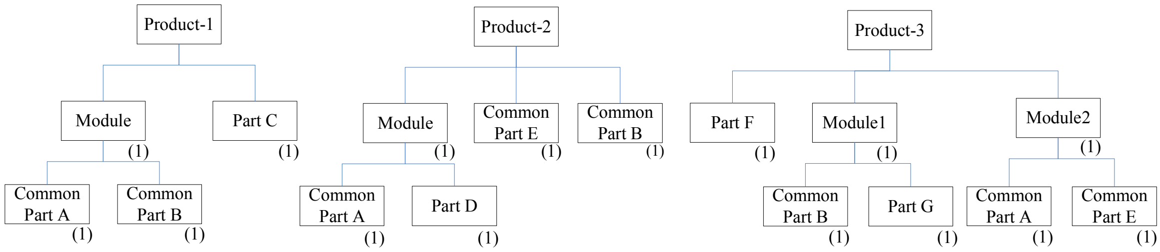
Step 4: As the solution-finding objective of this study is a problem of minimization, we therefore conduct reciprocal calculation on the fitness function by roulette to make it possible to have higher selection rate with high fitness value resulting in chromosomes with smaller fitness values having more reproduction chances. Randomly pick out two genes for single point crossover.

Step 5: Randomly pick out a gene to convert certain value by single point mutation. Repeat steps 4~5 until requested generation.

4 Example

This study finds out a purchase model beneficial to the company under the circumstances of the assembly cost, purchase cost and limited capacity of different parts supplied by various suppliers. We can get the optimized supplier combination and the optimized order quantity for each product by solution finding to get the profit base of the company in the industry. Hence, this study intends to take 3 products as an example. The parts include A, B, C, D, E, F, and G. And A, B, E are common parts in BOM, as shown in Fig. 2. And the demand of each product is 200, 250 and 300 respectively. Therefore, this study takes three products, seven parts and three suppliers for each part for the manufacturer to select.

The selection benchmarks of each supplier are the purchase, transport and assembly costs with different capacity limit for each supplier. Tables 1~3 demonstrate the unit assembly costs of various suppliers of various products. The purchase cost, transport cost and production upper limit are as shown in Table 4. This scheme will allocate the order quantity suppliers of various parts deserve and get the lowest cost aim by different quantity combination leading to the final demands.



Note: (1) refers to the quantity of request parts for a finished product

Fig. 2 Product disintegrated by BOM

Table 1 Unit assembly cost (AC) of product 1

		AC					
		Part B			Part C		
		B1	B2	B3	C1	C2	C3
Part A	A1	14	13.8	12	-	-	-
	A2	13.3	12	13.3	-	-	-
	A3	14.3	11	13	-	-	-
Part B	B1	-	-	-	11.5	12	11.25
	B2	-	-	-	13	10.75	12.25
	B3	-	-	-	13.25	12	13.25

- : No-assembly relationship between two parts

Table 2 Unit assembly cost (AC) of product 2

		AC					
		Part D			Part E		
		D1	D2	D3	E1	E2	E3
Par A	1	1.75	14	13	-	-	-
	2	0.25	11.5	2.75	-	-	-
	3	4.25	2.25	13	-	-	-
Part B	1	-	-	-	13	4.25	11.75
	2	-	-	-	0.75	11	14
	3	-	-	-	2.25	13	13
Part D	1	-	-	-	14	11	11
	2	-	-	-	11.5	13.5	11.25
	3	-	-	-	4.25	11	13.25

: No-assembly relationship between two parts

Table 3 Unit assembly cost (AC) of product 3

		AC								
		Part E			Part F			Part G		
		E1	E2	E3	F1	F2	F3	G1	G2	G3
Part A	A1	11.75	14	13	-	-	-	14.3	11	13.3
	A2	10.25	10.8	12.	-	-	-	13	10.8	12.3
	A3	11.5	13.5	11.	-	-	-	12	14	13
Part B	B1	-	-	-	12	12	12.8	11	11.3	13.3
	B2	-	-	-	13	12.5	12	10.5	12.3	12.5
	B3	-	-	-	13	12.3	13	11.3	12.8	12

- : No-assembly relationship between two parts

Table 4 Relevant data of various parts suppliers (purchase cost (PC), transport cost (TC) and production capacity upper limit (CUL))

		PC	TC	CUL
Part A	A1	107	47	200
	A2	60	67	790
	A3	110	69	525
Part B	B1	81	57	600
	B2	109	60	275
	B3	70	75	940
Part C	C1	86	53	550
	C2	85	59	400
	C3	77	81	365
Part D	D1	90	79	866
	D2	100	51	545
	D3	103	34	325
Part E	E1	95	32	404
	E2	98	68	745
	E3	89	71	655
Part F	F1	80	64	890
	F2	79	56	400
	F3	95	72	785
Part G	G1	89	80	965
	G2	99	78	565
	G3	100	82	406

To solve the example case of this study, we take generations respectively: 200, 400; populations: 200, 300; cross rates: 0.4, 0.6; mutation rates: 0.02, 0.05 as the genetic parameters for this study as shown in Table 5. Finally, in accordance with these parameters setting, we get the best setting of generation: 200; population: 300; crossover rate: 0.6; mutation rate: 0.05. At this time, the optimized supplier combination of various parts are respectively A1, A2, B2, B3, C1, C2, C3, D2, E1, E3, F3 and G1 with supply quantities as shown in Table 6 while the lowest cost of these supplier combinations is 455459.75 as converged as shown in Fig. 3.

Table 5 Various fitness values produced by different populations, generations, crossover rates and mutation rates

	PS	200		300	
GEN	CR / MR	0.4	0.6	0.4	0.6
200	0.02	456449.35 (a)	456899.35 (e)	456889.25(i)	457341.55(m)
	0.05	456672.2 (b)	458927.7 (f)	455742.75(j)	**455459.75 (n)**
400	0.02	458315.65 (c)	456144.95 (g)	459159.3 (k)	456608.6 (o)
	0.05	459534.55 (d)	458492.05 (h)	457681.25(l)	456714.8 (p)
PS: Population Size; GEN: Generation; CR: Crossover Rate; MR: Mutation Rate					

Table 6 The quantity that the selected suppliers need to supply in each part

Common/Non-Common	Part	Product	Supplier	Supply Quantity
Common Part	A	1	A1	12
			A2	188
		2	A2	250
		3	A2	300
	B	1	B2	60
			B3	140
		2	B3	250
		3	B3	300
	E	2	E1	250
		3	E3	300
Non-Common Part	C	1	C1	18
			C2	161
			C3	21
	D	2	D2	250
	F	3	F3	300
	G	3	G1	300

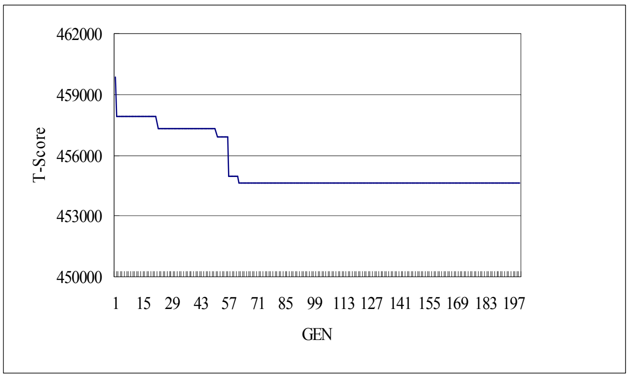


Fig. 3 Convergence process of combination (n)

5 Conclusion

This paper proposed an integrated selection model to offer the manufacturers selections of multi-products parts suppliers, making them more efficient in solving the problem. BOM is applied to represent the combinations of various product parts or modules and clearly calculate the total demand for various parts leading to the most appropriate supplier combination by GA. Hence, this model can deal with products composed of many different complex parts as well as predict the total cost of different supplier combinations in case of multi-products to serve as the reference to decision making. Therefore, in the following research, we can add purchase time, assembly time and quality to serve as the criterions for supplier selection to make the model perfect and make it more practical in real industry, enhancing the optimized decision making of various manufacturers in production and supplier selection.

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