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Schedule of a Resource-constraint Manufacturing System Based on GA

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Abstract: The purpose of this study is to verify a schedule mechanism based on Theory of constraint for a Resource-constraint Manufacturing System while in face of peak demand in certain period for the whole system, the system would achieve a holistic profitability. A numerical example has been adopted to demonstrate the efficiency of the proposed schedule mechanism based on TOC and as the processing procedure is a typical target allocation problem, genetic algorithm was used in the computation. The proposed mechanism based on TOC is far more efficient compared with the formal mechanism based on the quantity of the order.

Key words: Capacity allocation, genetic algorithm, theory of constraints

INTRODUCTION

In recent years there has been increasing concern about the deteriorating state of manufacturing competitiveness. In response to this declining competitiveness, flexible technology has been suggested as a means of coping with such a competitive situation (Cole and Jacob, 2002; Troxler and Blank, 1989). A Flexible Manufacturing System (FMS) is supposed to help regain competitiveness through improvements in productivity as well as quality. In addition, an FMS, with its ability to respond effectively to changing circumstances, can contribute toward gaining a competitive edge by reducing vulnerability due to demand variations, product mix variations and technological improvements in production (Bhattacharya and Vasant, 2007). Yet, despite these potential benefits, the adoption rate of flexible technology has been relatively slow. As suggested by Torabi *et al.* (2006), one major barrier to the adoption of flexible technology has been the lack of adequate methodologies for evaluating and justifying such expensive investments (Blackstone, 2001; Belvedere and Grando, 2005).

In general, we can divide the implementation procedure of flexible technology into the following three steps. The first step is investment appraisal, in which areas that require flexible technology are identified and then it is checked as to whether the investment is likely to be profitable. The second step is technology selection. In this step, the acquisition strategy is determined, several competing alternatives for the required manufacturing technology are evaluated and the best technology is determined. The last step is technical installation, in which the selected technology is installed.

In this study, we investigate a two echelon manufacturing system consist of multi-manufacturers and multi-distributors, we proposed a optimal production allocation mechanism based on Theory of Constraints (TOC) in face of meeting peak demand in certain period for the whole system (Lee *et al.*, 2002; Luebbe and Finch, 1992). The TOC is a global managerial methodology that helps the manager to concentrate on the most critical issues. It has been applied to a wide range of fields including Operation (Production), Finance and Measures, Project, Distribution and Supply Chain, Marketing, Sales, Managing People and Strategy and Tactics, The TOC-based strategy is now being implemented by a growing number of companies. The performance reported by the implemented companies includes reduction of inventory level, lead-time and transportation costs and increasing forecast accuracy and customer service levels. As the programming model we set up for the system is a NP-hard problem, Genetic algorithm (GA) has been selected in solving the optimal model in our work (Leng and Chen, 2012).

During the last decade, there has been a growing interest using Genetic Algorithms (GA) to solve a variety of single and multi-objective problems in production and operations management that are combinatorial and NP-hard. GA is heuristic search techniques inspired from the principles of survival-of-the-fittest in natural evolution and genetics (Naso *et al.*, 2007; Primrose and Leonard, 1991). However, Gas are generally slow and the average time that a well-configured GA would need to search for a satisfactory solution of the entire supply-chain problem may be too high for practical use in a real industrial context, where the decision algorithm must provide a solution in relatively short times. Namely, we use the GA to perform demand-to-production center assignment and the production sequencing at each center while the remaining part of the whole scheduling problem is handled by constructive heuristic algorithms. This approach leads to a hybrid evolutionary algorithm in which the GA constitutes the core of the search strategy while multiple heuristic rules called in specific circumstances contribute to reconstruct a feasible solution that satisfies all the constraints and objectives (Simatupang *et al*., 2004; Lee *et al*., 2002).

DESCRIPTION AND FORMULATION OF THE PROBLEM

The model we investigate in this study is a two-echelon production-distribution manufacturing system consists of M manufacturers and N retailers. Normally, we assume that M>N, as shown in Fig. 1.

In the system, all manufacturers are belonged to the same enterprise which can not only produce products with its own brand but also capable of dealing with the ODM (Original Design Manufacture) order for other companies, so each of the these manufacturer may have the choice to either focus on the internal business or other manufacturing outsourcing services and each manufacturer pursuit the maximization of its own performance, however, still they have to follow the direct instruction from the headquarters of the company, the limitation of the manufacturers capacity will not be considered in the model. We assume that different manufacturer produce certain product of different type, hence, we notei = 1, 2,..., t,..., r,..., w,...M for the manufacturers which produce three types of products which are A, B and C separately and W_i stand for the maximum capacity of the manufacturer.

Meanwhile, the manufacturing enterprise distributes its product via certain distributors. In regular sales seasons, the distributors order the product from the manufacturers, we note them as D_j, j = 1, 2,..., N and the production schedule are made based on the sales information provided by the distributors and it's obviously that the accuracy of information are far more different from each other among those distributors for the profit consideration of their own. The inaccuracy information would lead to overstock for the manufacturers and heavily jeopardize the profitability of whole manufacturing system. However, in particular sales period such as Christmas or spring festival, shortage of products would appear inevitably, even with overtime working strategy for the manufacturers, it is still hardly satisfy the peak demand in the period due to the constraints of funds

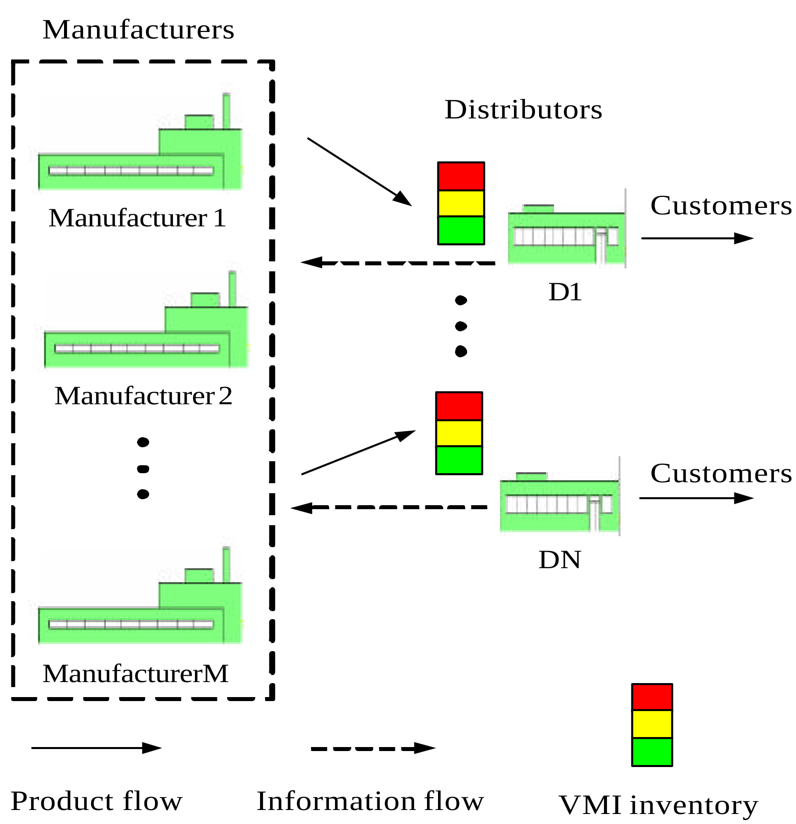

Fig. 1: A Production-distribution manufacturing system

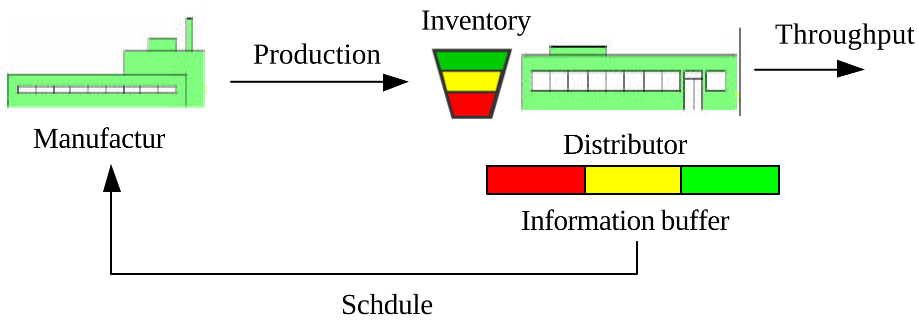

Fig. 2: Allocation mechanism based on TOC

available F and production capacity, although the distributor believe that the more inventories they have the higher profit they would achieve. Hence the main issue in this period is how to optimal the production allocation to maximize the profit of the entire manufacturing system.

Though the amount of the order is often considered as a main factor in priority decision, the information accuracy remains a leading concern for the manufacturer. Thus, we proposed an allocation mechanism based on TOC which use the information accuracy level as a buffer to schedule the production allocation in the system as shown in Fig. 2.

In contrast with the amount-oriented schedule, TOC-based mechanism emphasis the information accuracy of each distributor in daily operation. With different information accuracy level U_j, the higher value of the index the more product those distributor could have. By doing so, it will not only be a schedule mechanism but also an incentive for the whole manufacturing system to be more cooperative.

The objective function of our optimal model is to maximize the profit of the manufacturing system:

$$\max \sum_{j=1}^{N} U_j \left[(1-\prod_{i=1}^{M}(1-p_{ij})^{x_{ij}} \right]$$

In which p_{ij} stands for the possibility of the demand be satisfied when one batch of overtime production work be allocated to a certain manufacturer for a certain distributor.

According to the TOC-based mechanism, it is necessary to satisfy minimum requirement of each distributor:

$$\sum_{i=1}^{M} x_{ij} \ge U_j \cdot \sigma \cdot \left(\sum_{i=1}^{M} W_i \right)$$

is the flexible coefficient that the production capacity been put into use for the basic needs of the distributors and x_{ij} represent the number of batches of overtime work be allocated to manufacturer i for distributor j. While the amount-oriented schedule focus on the amount of distributors need:

$$\sum_{i=1}^{M} x_{ij} \ge \text{Max}\left\{ D_j, D_{j-1}, \cdots, D_1 \right\}$$

However, the schedule process has been limited to certain constraints, first of all is the funds that could be put into production which often be used in material procurement, labourage etc.

$$\sum_{j=1}^{N}\sum_{i=1}^{M} c_{ij} x_{ij} \le F\beta_\theta, \quad \theta \in [A,B,C]$$

c_{ij} is the overtime production cost of each batch that manufacturer i be allocated to distributor j ; stands for the proportion of each kind of product that satisfy the distributors basic needs. And of course the schedule process will also be limited by the capacity constraint:

$$\sum_{j=1}^{N} x_{ij} \le W_i$$

A GA BASED SOLUTION PROCEDURE

Model 1 is a typical target allocation mathematical problem which has been researched by many scholars. And various methods have been proposed in various literatures[16]-[18]. However, because of the large amount of manufacturers and retailers exist in a real manufacturing system and the efficiency of the Genetic algorithm in solving analogous issues, we choose an improved genetic algorithm in our research.

Prior to the application of GA, it is important to define an encoding strategy to transform a generic solution of the problem into a string of symbols suitable to the application of genetic operators. In GA literature, an

	Distributors			
Manufacturers	x_{11}	x_{12}	...	x_{1N}
	...	...	...	...
	x_{M1}	x_{M2}	...	x_{MN}

Fig. 3: Chromosomal representation of solution

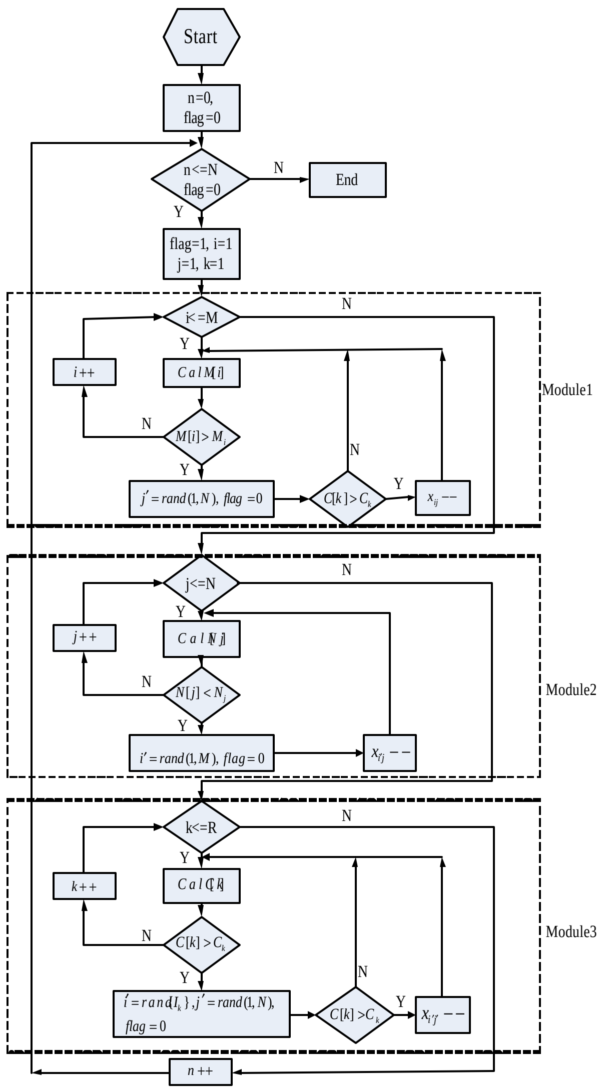

Fig.4: Structure of the race quality examination and rectify procedure

encoded solution is generally referred to as chromosome and a single parameter of the solution vector is called a gene. Designing a more suitable chromosomal representation of a solution is a key issue for successful implementation of GA. For the problem under study, binary system is selected in chromosome coding, meanwhile the chromosome structure shown in Fig. 3 is selected, each chromosomal is a matrix and each gene represent the number of batches of overtime work be allocated to manufacturer for distributor.in the schedule process.

Different from the traditional GA, we set a brand new race quality examination and rectify procedure in the GA program which consists of three modules, as shown in Fig. 4.

Module1 is used to adjust row vector of the chromosomal, the main function is to make sure that the production batch would not exceed the max capacity of the manufacturers and:

$$\text{Cal } M[i] = \sum_{j=1}^{N} x_{ij}$$

Module 2 is used to adjust column vector of the chromosomal and its main function is to assure that the basic requirement of the distributors could be satisfied and:

$$\text{Cal } N[j] = \sum_{i=1}^{M} x_{ij}$$

Module 3 is the last adjust procedure to the chromosomal, with the command:

$$i' = \text{rand}\{I_k\}, j' = \text{rand}(1, N), \text{flag} = 0$$

Manufacturer who produce different type of product will be separated with each other and then the procedure will adjust the chromosomal with the proportion of the funds be put into different type of products and:

$$\text{Cal } C[k] = \sum_{I_k} \sum_{j=1}^{N} c_{ij} x_{ij}$$

Then following the trational GA procedure, we shall have the optimal prodcution allocation schedule of the manufacturing system.

NUMERICAL EXAMPLE

In this section we use practical data as numerical example to demonstrate the efficiency of our proposed model. The data were provided by a traditional manufacturing SME (small and medium enterprise) located in Henan province, China. The company owns seven manufacturing plants located in different places and each plants pursuit its own profitability although they have to follow the direction of the headquarters of the company.

The company distributes its products 4 main distributors and by the year 2009, it owns 15 plants which produce 3 main goods, 7 produce A, 2 for B and 6 for C. When face the peak demand sales period, the production funds in hand is F = 7500000 yuan and the proportion for each kind of product is, separately. The possibility of demand satisfaction of each production allocation process is given in Table 1.

And other production cost and information accuracy level are shown in Table2, and The final solutions with different mechanism are shown in Table 3 and 4 and the variations of the solution for different mechanism are shown in Fig. 5 and 6.

Table 1 Possbility of satifaction for the peak demand

	A1	A2	A3	A4	A5	A6	A7	B1	B1	C1	C2	C3	C4	C5	C6
S1	0.31	0.35	0.19	0.07	0.13	0.24	0.09	0.39	0.24	0.1	0.12	0.32	0.32	0.23	0.29
S2	0.15	0.24	0.04	0.26	0.19	0.20	0.21	0.17	0.31	0.23	0.11	0.23	0.1	0.12	0.07
S3	0.25	0.12	0.03	0.19	0.25	0.22	0.18	0.47	0.14	0.13	0.23	0.19	0.28	0.13	0.15
S4	0.29	0.07	0.19	0.13	0.05	0.19	0.28	0.09	0.43	0.35	0.09	0.21	0.02	0.03	0.32

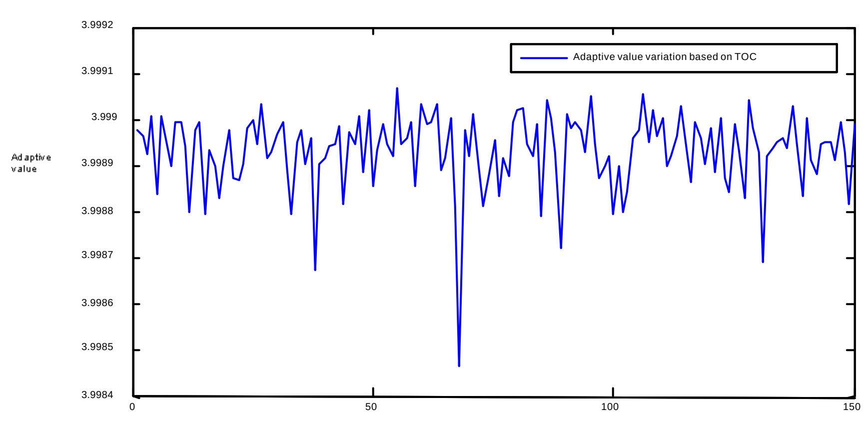

Fig. 5: Variation of the solution based on TOC mechanism

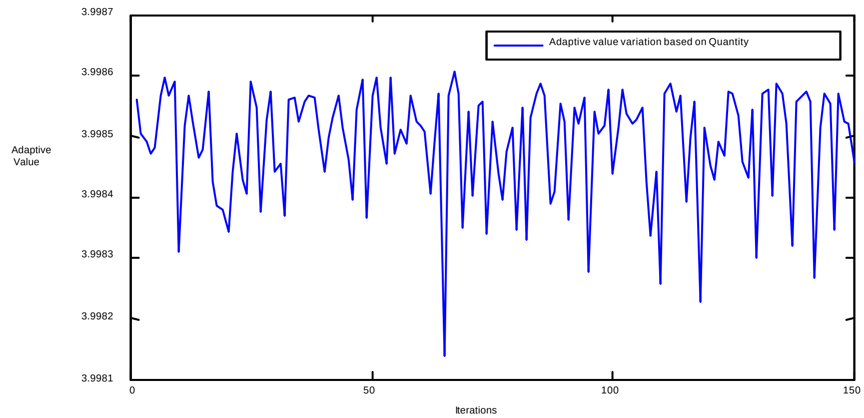

Fig. 6: Variation of the solution based on amount-oriented mechanism

Table 2: Production cost and information level

	S1	S2	S3	S4	Max capacity
A1	0.140	0.120	0.140	0.150	8
A2	0.110	0.130	0.150	0.100	7
A3	0.100	0.043	0.100	0.085	9
A4	0.130	0.130	0.130	0.125	5
A5	0.130	0.135	0.140	0.140	6
A6	0.150	0.130	0.150	0.110	8
A7	0.130	0.130	0.130	0.130	3
B1	0.015	0.010	0.010	0.010	10
B2	0.025	0.020	0.020	0.027	15
C1	0.050	0.050	0.050	0.065	12
C2	0.100	0.100	0.100	0.100	8
C3	0.060	0.060	0.060	0.060	4
C4	0.096	0.096	0.096	0.096	4
C5	0.020	0.020	0.020	0.020	4
C6	0.080	0.080	0.080	0.080	4
Distributor demands	20.000	30.000	25.000	15.000	
Information level	30.000	40.000	10.000	20.000	
Buffer level	18.000	25.000	10.000	16.000	

Table 3: Optimal schedule based on TOC mechanism

	A1	A2	A3	A4	A5	A6	A7	B1	B1	C1	C2	C3	C4	C5	C6
S1	5	7	0	0	0	0	0	0	0	0	0	2	4	4	0
S2	0	0	0	5	0	2	3	0	7	9	0	2	0	0	0
S3	2	0	0	0	4	0	0	10	0	0	2	0	0	0	0
S4	0	0	6	0	0	0	0	0	8	3	0	0	0	0	4
Optimal fitness value				3.999070		Throughput			99.97504						

Table 4: Optimal schedule based on amount-oriented mechanism

	A1	A2	A3	A4	A5	A6	A7	B1	B1	C1	C2	C3	C4	C5	C6
S1	6	7	0	0	0	0	0	0	0	0	0	4	3	0	0
S2	0	0	4	5	0	4	2	0	6	9	0	0	0	0	0
S3	1	0	5	0	1	0	1	10	0	0	2	0	1	4	0
S4	0	0	0	0	0	0	0	0	9	3	0	0	0	0	4
Optimal fitness value				3.998607		Throughput			99.94798						

CONCLUSION

In this study, we investigate the manufacturing system coordination mechanism in a two echelon manufacturing system consist of multi-manufacturers and multi-distributors, in order to deal with the information variation in the system such as ‘bullwhip’ effect, we proposed a optimal production allocation mechanism based on Theory of Constraints (TOC) in face of meeting peak demand in certain period for the whole system. And through a numerical example, we’ve shown the efficiency of our method in contrast with the traditional amount-oriented mechanism. The efficiency of the genetic algorithm we proposed in our research hasn’t been tested, future research might use certain Improved Genetic Algorithm. Though sufficient statistical power was realized, there was a relatively low response rate-future research may pre-elect data we surveyed to ensure eligibility.

The result also have demonstrate that in a manufacturing system which consist of one dominate supplier and multiple manufacturers, the upstream supplier should take the demand information accuracy rate as a key index while grouping the downstream members, some manufactures might have to reduce their profitability, however, the system would gain more in a centralized decision making process.

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