DSS Model for Profit Maximization at Customer Enquiry Evaluation Stage

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Abstract — **This paper presents an optimal method and a heuristic approach which aims at maximizing the profit when responding to a set of customer enquiries under limited capacity. The model takes into consideration the quantity of available-to-promise (ATP) which measures the capability to fill customer orders, along with enquiry quantity and product price. The optimal method and the heuristic approach are tested using ATP, product price and enquiry quantity each at their different levels. From the example conducted, it is found that (1) the optimal model can help to make appropriate decision for selecting a subset of enquiries, and (2) the heuristic approach can produce a result within 5% from the optimum achieved by optimal method for most parameter settings.**

Keywords: **Customer Enquiry; Demand; Decision Making; Capacity**

I. INTRODUCTION

The problem of customer enquiry evaluation has received scant attention in relevant literatures. An optimization model [4] was built for jointly determining price levels as well as selling effort levels when a company sells a certain product mix through a salesforce to heterogeneous accounts. A multi-period, multi-product model was developed with the objective of profit maximization, which addressed the cooperation between the production and the marketing department [5]. The advertising efficiency and price of products can be determined within their developed model. A variant of the modular bill of material, which is the mirror image of the choice tree in the generic and for materials replenishment, was developed [6]. Such hierarchical pseudo bills of material can be used for checking materials availability, allocating materials to customer orders and materials replenishment. The marketing and production consideration is very important in responding to customer enquiries, and there are a few studies addressing such issue [7-9]. Some other researchers proposed and developed a decision support system (DSS) approach to deal with customer enquiries [10-12]. Such DSS approach is critical during the production planning and control activities, working in conjunction with conventional manufacturing resource planning (MRPII) and enterprise resource planning (ERP) systems [13].

A SME manufacturing company needs to select a subset of enquiries to fulfill if the demand exceeds the materials availability and production capacity. This problem can be modeled with the objective of maximizing the profit from the selected enquiries. In the paper, a model to evaluate enquiries was developed to select a subset to fill under limited materials and production capacity. This model is fundamental in constructing DSS for SMEs [12]. Section 2 describes the problem and the entire assumptions. Section 3 presents the model and associated heuristic approach. In Section 4, a numerical experiment is illustrated. Finally in Section 5, we present concluding comments and future research directions.

II. CUSTOMER ENQUIRY EVALUATION

At the customer enquiry stage, a manufacturing company is usually confronted with problem that it is unable to fulfill all enquiries due to its limited materials and production capacity. One of the fundamental axioms of economics is for the firm to maximize profit. The profit function is thus selected as the objective in evaluating customer enquiries. As shown in Fig. 1, production capacity and materials availability are two constraints that

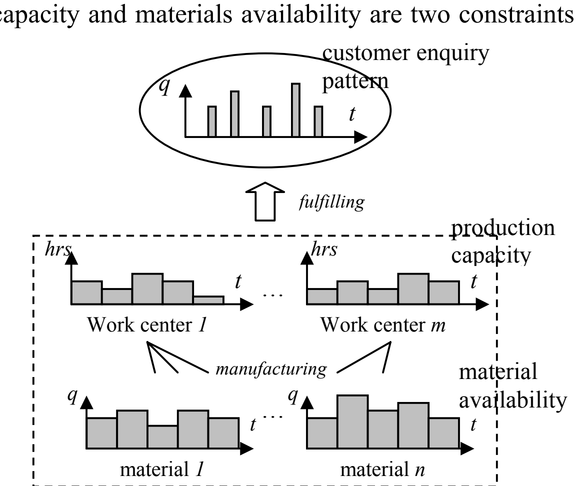


Fig. 1. Scenario of customer enquiry evaluation

affect the extent of the fulfillment.

A DSS framework to respond to customer enquiries for SMEs, in which available-to-promise (ATP) is selected as a criterion to measure a firm's capability to fill customer demands, is presented in [12]. A heuristic method was also developed to compute ATP based on work center's available working time and materials availability [14]. These studies pave the way for building a measurement system which can be used to evaluate customer enquiries. The proposed study in this paper focuses on the model and associated heuristics for evaluating customer enquiries. The assumptions of this research are:

1) One product only
2) mateiral availability and production capacity are known and deterministic
3) "full-or-nothing" demand fufillment policy
4) product structure and production routing are known
5) inventory holding cost, manufactuirng lead time, and unit processing time of every resource are known and deterministic
6) production capacity of work centers may neither be borrowed nor lent between different period
7) material availability is accumulative
8) product sales price are time dependent

III. PROPOSED MODEL

A. Optimal method

The notations in the model are as follows.

Indices:

i - index of customer enquiries, $i \in I$, where I is the number of enquiries

t - index of time buckets, $t \in T$, where T is length of planning horizon

Parameters:

t_i - requested time bucket for enquiry i, $i \in I$

$E_i(t_i)$ - quantity required by enquiry i in time bucket t_i, $t_i \in T$ and $i \in I$

$p(t)$ - sales price per unit of product in time bucket t

$ATP(t)$ - ATP quantity used for filling customer demands in time bucket t

c_h - unit inventory holding cost per time bucket

Decision variables:

α_i - binary variable stating whether accepting enquiry i

β_{ti} - fraction of $ATP(t)$ allocated to enquiry i

Objective function:

$$\underset{i \in I, t \in T}{Max}\ profit = f_{revenue} - f_{cost} \tag{1}$$

where, $f_{revenue}$ is revenue from accepting customer enquiries;

f_{cost} is inventory holding cost.

$$f_{revenue} = \sum_{i=1}^{I} [\alpha_i * E_i(t_i) * p(t_i)] \tag{2}$$

$$f_{cost} = \sum_{t=1}^{T} \{c_h * [ATP(t) * (T-t)]\} - \sum_{i=1}^{I} [c_h * \alpha_i * E_i(t_i) * (T-t_i)] \tag{3}$$

Constraints:

1) Customer requested quantity

$$\sum_{t=1}^{T} \beta_{ti} = \alpha_i \quad \forall i \in I \tag{4}$$

2) ATP quantity

$$\sum_{i=1}^{I} \beta_{ti} * E_i(t_i) \le ATP(t) \quad \forall t \in T \tag{5}$$

3) Fraction of ATP in time bucket t allocating to enquiry i

$$0 \le \beta_{ti} \le 1 \quad \forall i \in I \quad \forall t \in T \tag{6}$$

4) Domain constraints

$$t_i, E_i(t_i), p(t), ATP(t) \ge 0 \quad \forall i \in I \quad \forall t \in T \tag{7}$$

$$\alpha_i = 0 \text{ or } 1 \quad \forall i \in I \tag{8}$$

The $ATP(t)$ in the above model represents the fulfillment capability. It is bucketized, typically in weeks. The quantity of ATP is based on available working time of associated work centers as well as the materials availability of all related components. Equation 3 is the cost incurred by accepting certain customer orders which consists of two items. The first item in f_{cost} represents the total inventory holding cost without accepting any customer order; the second item is the decreasing inventory holding cost by accepting these orders. Equation 4 constrains the allocation fraction β_{ti}, stating that there is an equational relationship between the sum of allocation fractions from ATPs to a specific enquiry and the decision variable α_i. Equation 5 is another constraint for β_{ti}. It states that the allocated quantity from every ATP within each time bucket should not exceed the ATP quantity in the same time bucket. This model provides an adaptive combination of the inventory holding cost and the profit associated with the acceptance of customer enquiries. Thus, this model can support management decisions in practice.

Apparently, the proposed model is a mixed 0-1 linear programming model, and its global optimum can be easily obtained by some commercially available optimization solver such as LINGO [15]. In Section 4, we will test this model by a number of variants.

B. Heuristic Approach

In order to facilitate the implementation of above described model in certain applications such as Web-based DSS for managing customer enquiries [12], a heuristic approach associated with this optimal model is developed in the paper. Because it is difficult to optimize a problem with lots of feasible possibilities in heuristic approach, a kind of measurement criterion must be developed to arrange enquiries in order of importance. In correspondence with above optimal model, following criterion is developed for enquiry *i*.

$$f_i = \frac{p(t_i) * E_i(t_i)}{\sum_i^I p(t_i) * E_i(t_i)} * \frac{E_i(t_i) * (T - t_i)}{\sum_i^I E_i(t_i) * (T - t_i)} \quad (9)$$

The two items of f_i represent the effect on profit of revenue and decreased inventory holding cost respectively, by accepting enquiry *i*. In terms of f_i, for i =1, 2, …, *I*, a sequence of importance for all considered enquiries can be arranged. Finally based on such sequence, the heuristics for evaluating customer enquiries can be developed in a sequential way as described bellow.

Notations used in the heuristic approach:

LIST_accep – an array in which element represents the accepted enquiry

n_accep – number of accepted enquiries

tb_max – maximum time bucket in **LIST_accep**

atp_cumulated –accumulative ATP quantity along time

enq_qty_cumulated – accumulative enquiry quantity along time

i – index of enquiry, i =1, 2, …, *I*

t – index of time bucket, t =1, 2, …, *T*

Step 1. Initialization.

LIST_accep = ϕ , *n_accep* = 0

Read enquiry $E_i(t_i)$ for i = 1, 2, …, *I*, ATP $ATP(t)$ and price $p(t)$ for t = 1, 2, …, *T*

Step 2. Ordering of enquiries.

Compute f_i by Equation 9 for i = 1, 2, …, *I*.

Arrange all enquiries in descending order of f_i

Set i = 1

Step 3. Arrange all accepted enquiries in ascending order of delivery time.

Add $E_i(t_i)$ to **LIST_accep**

Arrange **LIST_accep** in ascending order of t_i, for i = 1, 2, …, *n_accep*

atp_cumulated = 0, *enq_qty_cumulated* = 0

Set t = 1

Step 4. Update accumulative ATP and accumulative enquiry quantity.

atp_cumulated = *atp_cumulated* + $ATP(t)$

For i = 1, 2, …, *I*, if $t_i = t$, *enq_qty_cumulated* = *enq_qty_cumulated* + $E_i(t_i)$

Step 5. Evaluation of enquiry quantity and ATP.

If *atp_cumulated* < *enq_qty_cumulated*, delete $E_i(t_i)$ from **LIST_accep**, go to Step 6

Otherwise, *atp_cumulated* = *atp_cumulated* - *enq_qty_cumulated*, *enq_qty_cumulated* = 0, go to Step 7

Step 6. Condition 1

If $i < I$, $i = i$ +1 and go to Step 3;

Otherwise, go to Step 8

Step 7. Condition 2.

If $t <$ *tb_max*, $t = t$ +1, and go to Step 4;

Otherwise, *n_accep* = *n_accep* +1, and go to Step 6

Step 8. Output and termination.

Output **LIST_accep** which consists of *n_accep* enquiries.

Stop

The main idea in this procedure is to fulfill the demands with high f_i as much as possible because they will bring in higher profit for companies. Therefore, these enquiries have high priority to use the available ATP quantities.

IV. NUMERICAL EXPERIMENT

A. Parameter design

In order to test the applicability of the proposed model and compare the results obtained by optimal method and heuristic approach, a number of variants are used to test the model. Three parameters of the model, ATP, product price and enquiry, are selected as the variants to test the model. For each parameter, it is assumed that there are four different types of variants: constant (C), linear increase (LI), linear decrease (LD) and random (R). The parameter combinations are listed in Table 1. Each level of ATP, price and enquiry quantity sum are defined respectively as below.

Table 1. Model parameters and levels

No of enquiries	15
No of time buckets	12
ATP levels	C, LI, LD, R
Price levels	C, LI, LD, R
Enquiry quantity sum levels	C, LI, LD, R

1) ATP settings. There are four settings for ATP along time, as shown in Fig. 2. The total sum of ATP and average ATP along 12 time buckets are 2400 units and 200 units, respectively.

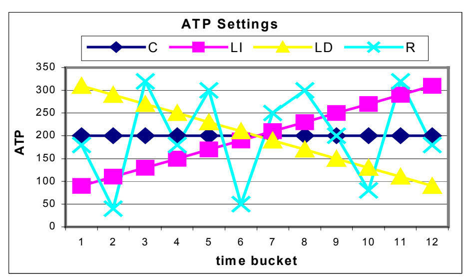


Fig. 2. Four settings for ATP along time

2) Sales price settings: Four settings are set for sales price illustrated in Fig. 3. The average sales price during 12 time buckets for all four settings is $10 per unit.

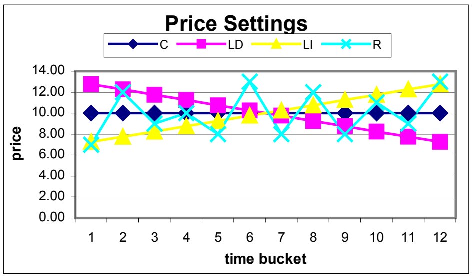


Fig. 3. Four settings for sales price along time

3) There are four settings for the enquiry quantity sum during each time bucket, as shown in Fig. 4. The total enquiry quantity for all four settings is 3000 units.

enquiry	time bucket 1	2	3	4	5	6	7	8	9	10	11	12	
E1				250									
E2											170		
E3		250											
E4	250												
E5					250								
E6			160										
E7										250			
E8							120						
E9									250				
E10								250					
E11						250							
E12							130						
E13											80		
E14			90										
E15												250	total
sum of req qty	250	250	250	250	250	250	250	250	250	250	250	250	3000

(a) Constant enquiry quantity sum

enquiry	time bucket 1	2	3	4	5	6	7	8	9	10	11	12	
E1	200												
E2	215												
E3				325									
E4							235						
E5		205											
E6			250										
E7										145			
E8									175				
E9								205					
E10		180											
E11						265							
E12			105										
E13					295								
E14												85	
E15											115		total
sum of req qty	415	385	355	325	295	265	235	205	175	145	115	85	3000

(b) LD enquiry quantity sum

enquiry	time bucket 1	2	3	4	5	6	7	8	9	10	11	12	
E1								295					
E2							265						
E3	85												
E4												165	
E5											175		
E6						235							
E7			145										
E8		115											
E9									325				
E10					205								
E11										180			
E12												250	
E13				175									
E14										175			
E15											210		total
sum of req qty	85	115	145	175	205	235	265	295	325	355	385	415	3000

(c) LI enquiry quantity sum

enquiry	time bucket 1	2	3	4	5	6	7	8	9	10	11	12	
E1		80											
E2	140												
E3			140										
E4			270										
E5						200							
E6					160								
E7										260			
E8						220							
E9									210				
E10								250					
E11						150							
E12					180								
E13											250		
E14				240									
E15												250	total
sum of req qty	140	80	410	240	340	570	0	250	210	260	250	250	3000

(d) Random enquiry quantity sum

Fig. 4. Four settings for enquiry quantity sum in every time bucket

There are totally 4*4*4 = 64 parameter settings in the combinations of ATP, sales price and enquiry quantity shown in Fig. 5.

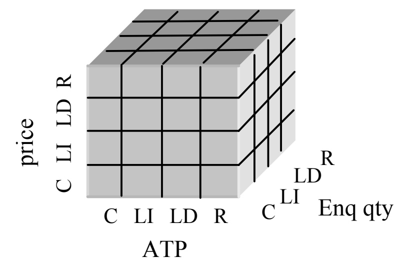


Fig. 5. Parameter combination for numerical experiment

B. Result and comparison

To facilitate comparison between results from optimal method and heuristics, we define four performance measures as below.

1) Profit = revenue – inventory holding cost with accepting a set of customer orders
2) Accepted proportion = No of enquiries accepted / total no of enquiries (15)
3) Enquiry fill rate (EFR) = enquiry quantity filled / total enquiry quantity, and
4) ATP used rate (AUR) = ATP used to fill accepted enquiries / total ATP quantity

We present in Table 2 the results in terms of various parameter settings designed in Fig. 5.

Table 2. Computation results

Para setting	Parameter description	Optimal method					Heuristic method				
		No of accep	Accep prop.	profit	EFR	AUR	No of accep	Accep prop.	profit	EFR	AUR
1	p-C;ATP-C;enq-C	11	73.3%	22330.0	0.797	0.996	10	66.7%	21710.0	0.777	0.971
2	p-C;ATP-C;enq-LD	11	73.3%	19525.0	0.692	0.865	10	66.7%	19180.0	0.698	0.873
3	p-C;ATP-C;enq-LI	11	73.3%	21550.0	0.8	1	11	73.3%	21550.0	0.8	1
4	p-C;ATP-C;enq-R	11	73.3%	22710.0	0.797	0.996	10	66.7%	20630.0	0.777	0.971
5	p-C;ATP-LI;enq-C	12	80.0%	21410.0	0.75	0.938	11	73.3%	21160.0	0.75	0.938
6	p-C;ATP-LI;enq-LD	9	60.0%	16190.0	0.59	0.738	8	53.3%	13050.0	0.527	0.658
7	p-C;ATP-LI;enq-LI	12	80.0%	22830.0	0.793	0.992	10	66.7%	21280.0	0.772	0.965
8	p-C;ATP-LI;enq-R	10	66.7%	19100.0	0.687	0.858	9	60.0%	18510.0	0.687	0.858
9	p-C;ATP-LD;enq-C	10	66.7%	21810.0	0.793	0.992	10	66.7%	20610.0	0.747	0.933
10	p-C;ATP-LD;enq-LD	12	80.0%	22685.0	0.79	0.988	11	73.3%	21410.0	0.76	0.95
11	p-C;ATP-LD;enq-LI	12	80.0%	19625.0	0.8	1	11	73.3%	18690.0	0.8	1
12	p-C;ATP-LD;enq-R	12	80.0%	21740.0	0.8	1	11	73.3%	19810.0	0.767	0.958
13	p-C;ATP-R;enq-C	12	80.0%	21820.0	0.793	0.992	12	80.0%	21820.0	0.793	0.992
14	p-C;ATP-R;enq-LD	10	66.7%	18600.0	0.675	0.844	10	66.7%	17505.0	0.645	0.806
15	p-C;ATP-R;enq-LI	11	73.3%	21885.0	0.798	0.998	11	73.3%	21885.0	0.798	0.998
16	p-C;ATP-R;enq-R	11	73.3%	21080.0	0.763	0.954	10	66.7%	21080.0	0.763	0.954
17	p-LD;ATP-C;enq-C	13	86.7%	21812.5	0.777	0.971	10	66.7%	21107.5	0.777	0.97
18	p-LD;ATP-C;enq-LD	11	73.3%	19806.3	0.692	0.865	10	66.7%	19133.8	0.7	0.873
19	p-LD;ATP-C;enq-LI	11	73.3%	20325.0	0.8	1	11	73.3%	20325.0	0.8	1
20	p-LD;ATP-C;enq-R	11	73.3%	22142.5	0.797	0.996	11	73.3%	21397.5	0.79	0.988
21	p-LD;ATP-LI;enq-C	12	80.0%	19847.5	0.75	0.938	11	73.3%	19570.0	0.74	0.925
22	p-LD;ATP-LI;enq-LD	9	60.0%	15737.5	0.59	0.738	8	53.3%	12500.0	0.527	0.658
23	p-LD;ATP-LI;enq-LI	12	80.0%	20970.0	0.793	0.992	10	66.7%	19148.8	0.772	0.965
24	p-LD;ATP-LI;enq-R	10	66.7%	17855.0	0.687	0.858	9	60.0%	16970.0	0.687	0.858
25	p-LD;ATP-LD;enq-C	11	73.3%	23545.0	0.793	0.992	10	66.7%	21585.0	0.747	0.933
26	p-LD;ATP-LD;enq-LD	12	80.0%	23690.0	0.79	0.988	11	73.3%	22475.0	0.76	0.95
27	p-LD;ATP-LD;enq-LI	12	80.0%	18867.5	0.8	1	12	80.0%	18867.5	0.8	1
28	p-LD;ATP-LD;enq-R	12	80.0%	22040.0	0.8	1	11	73.3%	21417.5	0.77	0.963
29	p-LD;ATP-R;enq-C	12	80.0%	20600.0	0.793	0.992	12	80.0%	20600.0	0.793	0.992
30	p-LD;ATP-R;enq-LD	10	66.7%	18521.3	0.675	0.844	10	66.7%	17576.3	0.645	0.806
31	p-LD;ATP-R;enq-LI	12	80.0%	20888.8	0.778	0.973	11	73.3%	20581.3	0.798	0.998
32	p-LD;ATP-R;enq-R	11	73.3%	20187.5	0.763	0.954	10	66.7%	20187.5	0.763	0.954
33	p-LI;ATP-C;enq-C	11	73.3%	23087.5	0.797	0.996	10	66.7%	22312.5	0.777	0.971
34	p-LI;ATP-C;enq-LD	11	73.3%	19243.8	0.692	0.865	10	66.7%	19226.3	0.698	0.873
35	p-LI;ATP-C;enq-LI	11	73.3%	22775.0	0.8	1	11	73.3%	22775.0	0.8	1
36	p-LI;ATP-C;enq-R	11	73.3%	23277.5	0.797	0.996	10	66.7%	21772.5	0.777	0.971
37	p-LI;ATP-LI;enq-C	12	80.0%	22972.5	0.75	0.938	11	73.3%	22847.5	0.75	0.938
38	p-LI;ATP-LI;enq-LD	9	60.0%	16642.5	0.59	0.738	8	53.3%	13600.0	0.527	0.658
39	p-LI;ATP-LI;enq-LI	12	80.0%	24690.0	0.793	0.992	10	66.7%	23411.3	0.772	0.965
40	p-LI;ATP-LI;enq-R	10	66.7%	20345.0	0.687	0.858	9	60.0%	20050.0	0.687	0.858
41	p-LI;ATP-LD;enq-C	11	73.3%	21735.0	0.793	0.992	10	66.7%	20958.0	0.793	0.992
42	p-LI;ATP-LD;enq-LD	12	80.0%	21680.0	0.79	0.988	11	73.3%	20345.0	0.76	0.95
43	p-LI;ATP-LD;enq-LI	12	80.0%	20382.5	0.8	1	11	73.3%	19915.0	0.8	1
44	p-LI;ATP-LD;enq-R	12	80.0%	21440.0	0.8	1	10	66.7%	18912.5	0.777	0.971
45	p-LI;ATP-R;enq-C	12	80.0%	23040.0	0.793	0.992	12	80.0%	23040.0	0.793	0.992
46	p-LI;ATP-R;enq-LD	10	66.7%	18678.8	0.675	0.844	10	66.7%	17433.8	0.645	0.806
47	p-LI;ATP-R;enq-LI	11	73.3%	23188.8	0.798	0.998	10	66.7%	21303.8	0.762	0.952
48	p-LI;ATP-R;enq-R	11	73.3%	21972.5	0.763	0.954	10	66.7%	21972.5	0.763	0.954
49	p-R;ATP-C;enq-C	11	73.3%	23560.0	0.797	0.996	10	66.7%	23130.0	0.777	0.971
50	p-R;ATP-C;enq-LD	11	73.3%	19560.0	0.693	0.867	10	66.7%	19095.0	0.668	0.835
51	p-R;ATP-C;enq-LI	12	80.0%	22555.0	0.793	0.992	11	73.3%	22105.0	0.785	0.981
52	p-R;ATP-C;enq-R	12	80.0%	24190.0	0.797	0.996	11	73.3%	24010.0	0.793	0.992
53	p-R;ATP-LI;enq-C	11	73.3%	21720.0	0.74	0.925	11	73.3%	21720.0	0.74	0.925
54	p-R;ATP-LI;enq-LD	9	60.0%	16020.0	0.59	0.738	9	60.0%	14835.0	0.552	0.69
55	p-R;ATP-LI;enq-LI	12	80.0%	24465.0	0.793	0.992	10	66.7%	21925.0	0.768	0.96
56	p-R;ATP-LI;enq-R	9	60.0%	20790.0	0.687	0.858	9	60.0%	20790.0	0.687	0.858
57	p-R;ATP-LD;enq-C	11	73.3%	23630.0	0.793	0.992	10	66.7%	22020.0	0.777	0.971
58	p-R;ATP-LD;enq-LD	12	80.0%	22640.0	0.79	0.988	11	73.3%	21565.0	0.748	0.935
59	p-R;ATP-LD;enq-LI	12	80.0%	19800.0	0.788	0.985	11	73.3%	19375.0	0.788	0.985
60	p-R;ATP-LD;enq-R	12	80.0%	22810.0	0.8	1	11	73.3%	22320.0	0.767	0.958
61	p-R;ATP-R;enq-C	12	80.0%	22310.0	0.793	0.992	12	80.0%	22310.0	0.793	0.992
62	p-R;ATP-R;enq-LD	10	66.7%	19040.0	0.675	0.844	10	66.7%	17055.0	0.62	0.775
63	p-R;ATP-R;enq-LI	12	80.0%	23125.0	0.793	0.992	11	73.3%	22435.0	0.795	0.994
64	p-R;ATP-R;enq-R	11	73.3%	22780.0	0.76	0.95	10	66.7%	22490.0	0.763	0.954
	Min	9	60.0%	15737.5	0.59	0.738	8	53.3%	12500	0.527	0.658
	Max	13	86.7%	24690	0.8	1	12	80.0%	24010	0.8	1
	Average	11.2	74.4%	21156.1	0.75	0.94	10.3	68.9%	20255.9	0.74	0.92

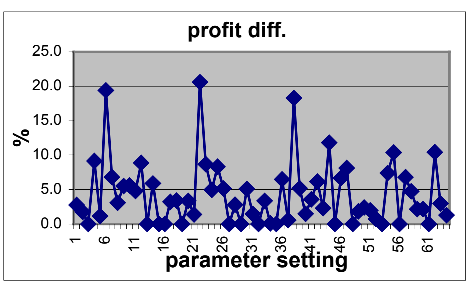
From Table 2, at overall level, average 11.2 enquiries out of 15 are filled by optima method, and 10.3 by heuristic approach. Optimal method and heuristic approach are compared based on the gap which defined as the difference between optimal and heuristic results. We present a comparison between the optimal result and heuristic result in Table 3. Another comparison in chart form is shown in Fig. 6. Because the ATP used quantity is equal to enquiry filling quantity, the EFR difference proportion is the same as the AUR's.

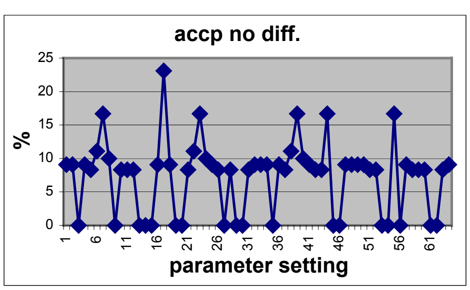
Table 3. Comparison between optimal and heuristic result

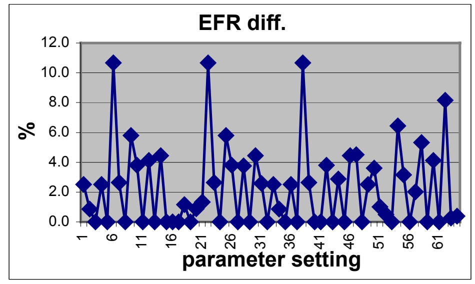
gap (%)	criteria					
	Profit		EFR		Accep. No.	
	No. of cases	percent (%)	No. of cases	percent (%)	No. of cases	percent (%)
< 5	41	64.1	56	87.5	18	28.1
5 ~ 10	17	26.6	5	7.8	36	56.3
>10	6	9.4	3	4.7	10	15.6

From Table 2, Table 3 and Fig. 6, we can reach the following conclusions.

1) The proposed model provides a solution based on available capacity for decision makers when they respond to a set of customer enquiries
2) For the proposed model, the heuristic approach is able to produce a feasible solution which is close to the result generated by optimal method. Especially, for the criteria of profit and EFR, 64.1% and 87.5% of heuristic results are within 5% gap from optimal result, respectively. 90.7% instances are within 10% gap for profit. Similarly, for EFR, 95.3% instances are within 10% gap. Comparatively, the difference for accepted number is marginally high. The reason for this is because of the modeling assumption of "full-or-nothing" fulfillment policy.
3) For several parameter settings (Setting 6, 22, 38), the profit difference is around 20% and the EFR difference is greater than 10% between optimum and heuristic result. These exceptions arise in the parameter patterns where ATP is linear increasing and sum of enquiry quantity in every time bucket is linear decreasing. The exception is supposed to be solved by applying in succession a kind of post-selection procedure which takes account of previously selected enquiries. Such improvement will be undertaken in our following research.







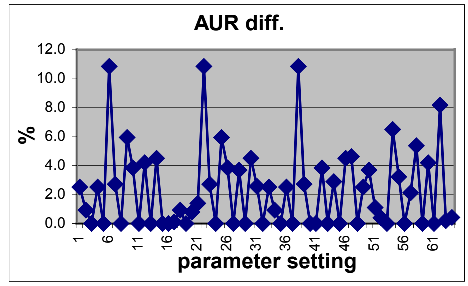


Fig. 6. Comparison chart between optimum and heuristic result

V. CONLUSIONS

In this paper we have studied a model and its associated heuristic approach of profit maximization at customer enquiry evaluation stage. This is assumed that SME firm has limited production capacity and materials availability. Besides, a numerical experiment was conducted and it was found that the proposed model is able to provide solutions under the desired objective function.

The advantage of this model lies in its ability to allow decision maker to adjust certain parameters to make a "what-if" analysis. The experiment result shows that the developed heuristic approach can provide a feasible solution close to the optimum solution generated from the optimal method. This will facilitate future implementation of this model in certain projects such as Web-based DSS development for managing customer enquiries.

However, the current model is relatively simple. It consists of only one product and one cost function. Therefore, our further research will be focused on developing an improved model by adding manufacturing cost, lost sales cost and backordering cost into the objective function. Such model can provide extra solution for postponing certain customer orders in order to make better profit for companies. We will also conduct further data analysis to work out the better fulfillment pattern for different parameter settings.

REFERENCES

[1] D. C. Yen, D. C. Chou, and J. Chang, "A synergic analysis for Web-based enterprise resource planning systems", *Computer Standards and Interfaces*, vol. 24, no. 4, pp.337-346, 2002.

[2] M. H. Xiong, S. B. Tor, and Rohit Bhatnagar, "Manage customer enquiries at the customer enquiry stage for SMEs – problems and solutions", Proceedings of the 17th International Conference on

Production Research (ICPR'2003), Blacksburg, Virginia, USA, 2003.

[3] S. Chang, C. Yang, H. Cheng, and C. Sheu, "Manufacturing flexibility and business strategy: an empirical study of small and medium sized firms", *International Journal of Production Economics*, vol.83, no.1, pp.13-26, 2003.

[4] S. Albers, "CAPPLAN: a decision-support system for planning the pricing and sales effort policy of a salesforce", *European Journal of Marketing*, vol.30, no.7, pp.68-82, 1996.

[5] G. Ulusoy, and T. Yazgac, "Joint decision making for production and marketing", *International Journal of Production Research*, vol.33, no.8, pp.2277-2293, 1995.

[6] J. W. M. Bertrand, M. Zuijderwijk, and H. M. H. Hegge, "Using hierarchical pseudo bills of material for customer order acceptance and optimal material replenishment in assemble to order manufacturing of non-modular products", *International Journal of Production Economics*, vol. 66, pp. 171-184, 2000.

[7] B. Kingsman, L. Hendry, A. Mercer, and A. de Souza, "Responding to customer enquiries in make-to-order companies – problems and solutions", *International Journal of Production Economics*, vol. 46/47, pp.219-231, 1996.

[8] B. Kingsman, W. Lee, L. Hendry, A. Mercer, and E. Wilson, "Integrating marketing and production planning in make-to-order companies", *International Journal of Production Economics*, vol.30/31, pp.53-66, 1993.

[9] L. Hendry, and B. Kingsman, "Customer Enquiry Management: Part of a Hierarchical System to Control Lead Times in Make-to-Order Companies", *Journal of the Operational Research Society*, vol.44, no.1, pp.61-70, 1993.

[10] D. N. Halsall, and D. H. R. Price, "A DSS approach to developing systems to support production planning control in smaller companies", *International Journal of Production Research*, vol.37, no. 7, pp.1645-1660, 1999.

[11] L. Hendry, "COPP: A Decision Support System for Managing Customer Enquiries", *International Journal of Operations and Production Management*, vol.12, no.11, pp.53-64, 1992.

[12] M. H. Xiong, S. B. Tor, Rohit Bhatnagar, L. P. Khoo, and S. Venkat, "A DSS approach to managing customer enquiries for SMEs at the customer enquiry stage", submitted to *International Journal of Production Economics*. 2003.

[13] D. Kehoe, and N. Boughton, "Internet Based Supply Chain Management – A Classification of Approaches to Manufacturing Planning and Control", *International Journal of Operations and Production Management*, vol.21, no.4, pp.516-524, 2001.

[14] M. H. Xiong, S. B. Tor, Rohit Bhatnagar, L. P. Khoo, and S. Venkat, "Extended dynamic BOM: a new approach to explode multilevel BOM", working paper.

[15] LinDo System Inc., *LINGO user's guide*. Chicago, Illinois 60622, 2001.