Price Quoting Method for Contract Manufacturer

S. Homrossukon, and W. Parinyasart

***Abstract*—**This is an applied research to propose the method for price quotation for a contract electronics manufacturer. It has had a precise price quoting method but such method could not quickly provide a result as the customer required. This reduces the ability of company to compete in this kind of business. In this case, the cause of long time quotation process was analyzed. A lot of product features have been demanded by customer. By checking routine processes, it was found that high fraction of quoting time was used for production time estimating which has effected to the manufacturing or production cost. Then the historical data of products including types, number of components, assembling method, and their assembling time were used to analyze the key components affecting to production time. The price quoting model then was proposed. The implementation of proposed model was able to remarkably reduce quoting time with an acceptable required precision.

***Keywords*—**Price quoting, Contract manufacturer, Stepwise technique, Best subset technique.

I. Introduction

PRICE quoting is one important process for contract manufacturing [1]. The quoting process would need good cooperation from the various sections of company. Therefore, it is time consuming process. In manufacturing industry, high fraction of the prices is from production section as it has been affected by lead time or production time. The more the difficulty of lead time determination, the longer the quoting time will be [2], [3]. To keep and satisfy the potential customer, a quick and accurate price quotation should be achieved whenever the customer request for a bid. Having the suitable quoting method would raise the efficient price quotation and customer satisfaction, consequently. The more the component of product, the difficulty of price estimating would be. Therefore, a lot of aiding methods have been conducted. A numbers of researches for price and/or cost quotation were listed and found that they have been usefully conducted via a computer based model [4]. But this work will proposed a method to construct a simple model of price quotation.

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S. Homrossukon is with the Industrial Statistics and Operational Research Unit (ISO-RU), Department of Industrial Engineering, Faculty of Engineering, Thammasat University, 12120, Thailand (Phone: 662-564-3002-9; fax: 662-564-3017; e-mail: tsamerji@engr.tu.ac.th).

W. Parinyasart is graduated student with the Industrial Statistics and Operational Research Unit (ISO-RU), Department of Industrial Engineering, Faculty of Engineering, Thammasat University, 12120, Thailand.

II. Problem Background

The case of interest is the contract electronic manufacturer providing the repair service and product made by order. The customers will demand to know the price of the service within a short period before signing a contract. The process of price quoting is displayed in Fig. 1. There are 7 main steps. Price quoting is started by receiving the order from the customer. In the next step, the data of purchasing is determined including product structure, data file, special process requirement, the number of product and the due date of price quoting. Then the product is determined in deep detail before it is designed. After that the production time is determined since it affects to labor and indirect labor and overhead cost. All details are rechecked again for an accurate data and the price is quoted, consequently.

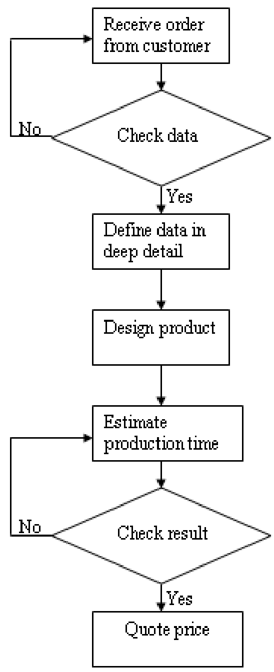

Fig. 1 Price quoting flow

There are a lot of customers and product styles that required a due. The complexity is that the produced product has a lot of components, then, a lot of processes are required. In this case, it was found that the case of interest could not quote the price in time as customer required, especially for the new product. This problem also affects to the competitive ability of the company if the competitor has higher ability on this issue.

Currently, the price is quoted in the standard form using computer worksheet. From historical data, this method has provided a precise result but it took much time to start price computing or quotation. The average quoting time required by customer was 1.5 day/product, approximately but it takes at least 3 days, currently. Therefore, the alternative quoting method that could consume shorter time and provide accurate result should be interested.

III. Methodology

Price quoting process is time consumer process. If the factor affecting such time could be determined, then the suitable method would be constructed. In this case, this work started by determining such factors. The cause effect diagram will be used as it is one of 7 tools providing a root cause analyses. After the primary effects are declared then, they will be analyzed using statistical analyses. Two statistical techniques including best subset and stepwise will be used to propose the quoting model in this work.

A. Best Subset Technique

The best subset is a technique used for statistically determining regression models. It is used to determine which variables should be included in a multiple regression model. Usually, F-test, R square adjusted R square or Mollow Cp is considered [5].

B. Step Wise Technique

Step wise regression is the statistic procedure to select the model when there are a large number of potential variables and when the selected model has no theory to base on [5]. Usually, F-tests are considered but possibly for t-tests, or adjusted R-square. The form of interest here is determination of variation on a forward selection. At each stage in the compute process, after a new variable is added, a test is performed to determine if some variables can be cut off without increasing the residual sum of squares (RSS). The procedure is terminated when the measure facto is optimized, or when the available improvement falls below the critical value [6].

C. Research Flow

Even though there are many types of product produced by the company of interest but they can be divided into a group based on their feature. Such feature includes the components, size, and etc. This work started by considering the most wanted alike products and used their quoting data to propose the new method of price quoting. From Fig. 1 and working information, it was found that the production time estimating step consumed highest fraction of time in quoting process. Such times were also changed when the product feature was changed. The quoting times of the other steps were not significantly different as they were routine process, then, their quoting time were determined as a constant value. In this case, it was useful if the factors affecting to production time estimating could be declared. Therefore, the statistical analyses were applied. The price quoting model, then, were determined using best sup-set and stepwise techniques. Both models were validated via the former quoting data. The most suitable model provided lower error. Therefore, the results were compared via mean absolute percent error (MAPE) [5]. Finally, the selected model will be implemented for upcoming order while the old quoting method was also parallel performed. This could validate the effectiveness of the new quoting method. The flow of this work is concluded in Fig. 2.

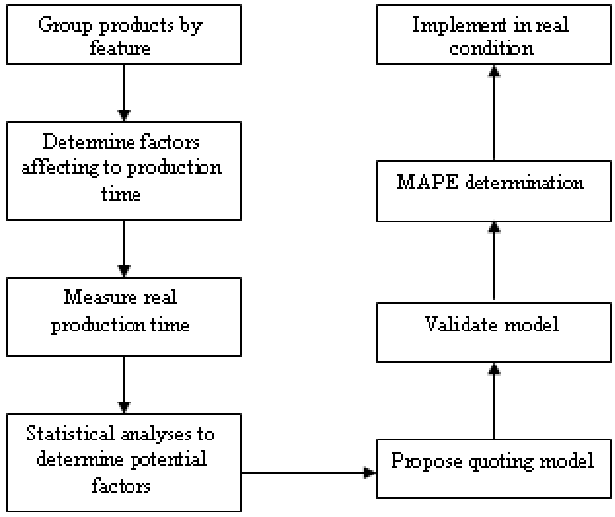

Fig. 2 Flow of Price Quoting Model Development

IV. Data Analyses and Result

A. Quoting Time Factors

From part *C* in session III, the quoting time mainly depended on the determination of production time. In this case, the factor affecting to the production time estimation was firstly determined. Based on the historical working data, it was found that the feature of product has affected to the production time estimating. The more the complicated feature needed longer the production time. This also affected to the difficulty of time estimating and to price quoting time, consequently. From historical data study, most of products were made in various sizes and from various types of components. Those components were manually or automatically assembled. In this case, it was concluded that there were 6 factors affecting to production time. The first one was area of product (A) affecting to an inspection time. The second one was the number of component placed by automatic machine (B). Even though the machine was used but it was able to assemble one component at a time. The third and the fourth one were the number of manually placed component(C) and the number of mechanic component (D), respectively. There was one component placed at a time and manual inspection required. The fifth one was the number of terminal (E) affecting to the soldering time. The final one was the number of packing component (F).

B. Potential Factor Determination

The assembling data of the group of interested product in the part were categorized based on the six factors of interest. The number of sample size was 30 for being satisfied the statistical view. First, the data properties such as normality

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and residual value were analyzed as shown in Fig. 3 and Fig. 4.

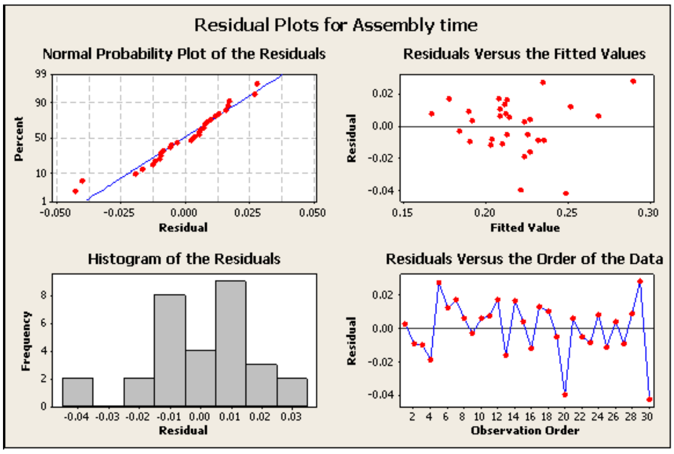

Fig. 3 Normality plot of production time data for various levels of factors

Regression Analysis: Assembly tim versus PCB area, Total Comp. , ...

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The regression equation is
Assembly time = 0.208 + 0.000004 PCB area + 0.000855 Total Comp. (SMD)
                - 0.00245 Total Comp. (Manual SMT)
                + 0.0116 Total Comp. (Mechanic) - 0.000252 Total terminal
                + 0.00337 Packing


Predictor                        Coef     SE Coef      T      P   VIF
Constant                      0.20791     0.04760   4.37  0.000
PCB area                   0.00000410  0.00000215   1.91  0.069   3.5
Total Comp. (SMD)           0.0008554   0.0003399   2.52  0.019  21.3
Total Comp. (Manual SMT)    -0.002451    0.004012  -0.61  0.547   1.7
Total Comp. (Mechanic)       0.011591    0.002130   5.44  0.000   2.0
Total terminal            -0.00025189  0.00008489  -2.97  0.007  21.3
Packing                     0.0033741   0.0008159   4.14  0.000   1.2

S = 0.0184943   R-Sq = 71.3%   R-Sq(adj) = 63.8%

Source                    DF     Seq SS
PCB area                   1  0.0003721
Total Comp. (SMD)          1  0.0016474
Total Comp. (Manual SMT)   1  0.0007380
Total Comp. (Mechanic)     1  0.0063476
Total terminal             1  0.0046093
Packing                    1  0.0058491


Unusual Observations

               Assembly
Obs  PCB area      time      Fit   SE Fit  Residual  St Resid
 20      5376   0.18120  0.22128  0.00841  -0.04008     -2.43R
 21      5460   0.27466  0.26883  0.01782   0.00583      1.17 X
 29      9408   0.31754  0.28946  0.01405   0.02808      2.34R
 30     10790   0.20597  0.24858  0.00898  -0.04261     -2.64R

R denotes an observation with a large standardized residual.
X denotes an observation whose X value gives it large influence.
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Fig. 4 Regression Analyses of production time data versus its affecting factors

From Fig. 3, even though the distribution of data was normal but there were 4 data showing high residual from the rest. Even though the potential factors of production time estimating were determined in Fig. 4 but it was also found that there were 4 unusual observations displayed. Further investigation found that the observations no. 20, no. 21 and no.29 had some different feature and process and more complicated than the others so these data were pulled out. For observation no. 30, the data was wrongly recorded. After correcting the unusual data, the normal distribution and regression of the rest were reanalyzed and the results were shown in Fig. 5 and Fig. 6, respectively.

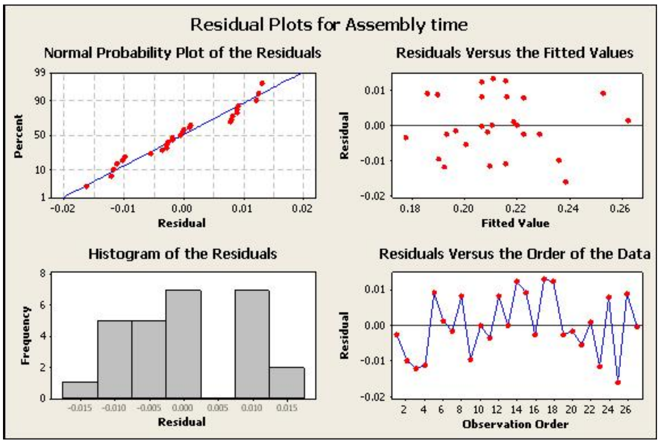

Fig. 5 Normality plot after data correction

Regression Analysis: Assembly tim versus PCB area, Total Comp. , ...

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The regression equation is
Assembly time = 0.227 + 0.000005 PCB area + 0.000586 Total Comp. (SMD)
                - 0.00370 Total Comp. (Manual SMT)
                + 0.00733 Total Comp. (Mechanic) - 0.000145 Total terminal
                - 0.00531 Packing


Predictor                        Coef     SE Coef      T      P   VIF
Constant                      0.22652     0.03039   7.45  0.000
PCB area                   0.00000482  0.00000126   3.81  0.001   3.8
Total Comp. (SMD)           0.0005855   0.0002138   2.74  0.013  30.0
Total Comp. (Manual SMT)    -0.003697    0.002300  -1.61  0.124   1.7
Total Comp. (Mechanic)       0.007330    0.001850   3.96  0.001   3.7
Total terminal            -0.00014483  0.00005559  -2.61  0.017  32.9
Packing                     -0.005313    0.002432  -2.18  0.041   2.7

S = 0.00967932   R-Sq = 84.6%   R-Sq(adj) = 79.9%

Analysis of Variance

Source          DF         SS         MS      F      P
Regression       6  0.0102570  0.0017095  18.25  0.000
Residual Error  20  0.0018738  0.0000937
Total           26  0.0121308


Source                    DF     Seq SS
PCB area                   1  0.0007992
Total Comp. (SMD)          1  0.0006550
Total Comp. (Manual SMT)   1  0.0001475
Total Comp. (Mechanic)     1  0.0066832
Total terminal             1  0.0015252
Packing                    1  0.0004470
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Fig. 6 Regression Analyses after data correction

Fig. 5 shows that the data distribution is normal. Then, further analysis was performed as shown in Fig. 6. It was found that the relationship between assembly time in hour unit (Y) and their affecting factors was determined as in (1);

$$Y=0.277+0.000005A+0.000586B-0.00370C +0.00733D- 0.000145E-0.00531F \quad (1)$$

This regression model provided low deviation at 0.0097 and quite high R-sq at 84.6% (better than before data correction). Further determination found that factor B (number of component placed by automatic machine) and E (number of terminal) had high variance inflation factors (VIP) showing that these two factors are not independent from each other. Therefore, the techniques of best subset and stepwise would be used to further determine the most potential affecting factors.

C. Quoting Model by Best Subset Technique

The potential factors counted for estimating production time were determined in this stage. By applying the best subset technique, the result was given as in Fig. 7. From (1), the regression shows the effect of all six factors. Therefore, the variables were group as the subset. There were 11 groups of variable considered for each case. Vars 1 meant that one variable was considered. In this case, it was found that the lowest Mallow C-p value was seven. Under such consideration, the lowest standard deviation and highest R-sq were achieved. Therefore, all six variables should be considered. Then, (1) should define the production time estimating equation.

Response is Assembly time

Vars	R-Sq	R-Sq(adj)	Mallows C-p	S	PCB area	Total Comp. (SMD)	Total Comp. (Manual SMT)	Total Comp. (Mechanic)	Total terminal	Packing
1	34.4	31.8	61.9	0.017840						X
1	17.3	14.0	84.0	0.020026				X		
2	65.1	62.1	24.2	0.013290	X			X		
2	58.4	54.9	32.9	0.014501	X					X
3	77.4	74.5	10.2	0.010910	X			X		X
3	68.8	64.7	21.5	0.012838		X		X	X	
4	78.7	74.8	10.6	0.010837	X		X	X		X
4	78.5	74.6	10.9	0.010896	X	X		X		X
5	82.6	78.4	7.6	0.010038	X	X		X	X	X
5	80.9	76.3	9.8	0.010512	X	X	X	X	X	
6	84.6	79.9	7.0	0.0096793	X	X	X	X	X	X

Fig. 7 Best subset analyses result

D. Quoting Model by Stepwise Technique

By applying stepwise technique, part of the result was shown as in Fig. 8. It was found that 3 variables should be considered as the result shows highest R-sq and lowest Cp. In this case, three potential factors included the PCB area (A) and the total comp mechanic (D) and the packing component (F).

Stepwise Regression: Assembly tim versus PCB area, Total Comp. , ...

Alpha-to-Enter: 0.15 Alpha-to-Remove: 0.15

Response is Assembly time on 6 predictors, with N = 27

Step	1	2	3
Constant	0.2926	0.2801	0.1770
Packing	-0.0099	-0.0129	-0.0076
T-Value	-3.62	-5.47	-3.55
P-Value	0.001	0.000	0.002
PCB area		0.00000	0.00001
T-Value		3.72	6.59
P-Value		0.001	0.000
Total Comp. (Mechanic)			0.0075
T-Value			4.40
P-Value			0.000
S	0.0178	0.0145	0.0109
R-Sq	34.41	58.40	77.43
R-Sq(adj)	31.79	54.93	74.49
Mallows C-p	61.9	32.9	10.2

Fig. 8 Stepwise analyses result

Then, their regression equation was further analyzed as in Fig 9 and was written in (2).

$$Y=0.177+0.000006A+0.00751D-0.00763F \qquad (2)$$

Regression Analysis: Assembly tim versus PCB area, Total Comp. , Packing

The regression equation is
Assembly time = 0.177 + 0.000006 PCB area + 0.00751 Total Comp. (Mechanic) - 0.00763 Packing

Predictor	Coef	SE Coef	T	P	VIF
Constant	0.17703	0.02723	6.50	0.000	
PCB area	0.00000636	0.00000096	6.59	0.000	1.7
Total Comp. (Mechanic)	0.007513	0.001706	4.40	0.000	2.5
Packing	-0.007632	0.002149	-3.55	0.002	1.7

S = 0.0109104 R-Sq = 77.4% R-Sq(adj) = 74.5%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	0.0093930	0.0031310	26.30	0.000
Residual Error	23	0.0027378	0.0001190		
Total	26	0.0121308			

Source	DF	Seq SS
PCB area	1	0.0007992
Total Comp. (Mechanic)	1	0.0070924
Packing	1	0.0015014

Fig. 9 Regression analyses by stepwise technique

Based on (1) all factors should be considered but only three factors required from (2). These two models, then, were validated and their results were compared via the historical data by MAPE determination. It was found that (2) provided lower MAPE than (1). In this case, (2) should be used for assembly time determination in price quoting process.

V. Discussion

The main effect of price quoting time of the case of interest was from production time or lead time estimation as mentioned before [2] [3]. The complexity of production process depends on the feature or the components of such product. This also affects to the production time as the process and cost are sequence-dependent [7]. High error of production time estimating leads to inaccurate price quoting. As it is difficult to get an exact production time for the new product, the estimating time could not be avoided. This work proposed production time estimating equation using two techniques. Their statistical analyses results were concluded in Table I.

TABLE I
COMPARISON OF STATISTICAL ANALYSES OF BEST SUBSET AND STEPWISE

Items	Best Subset	Stepwise
S	0.00967932	0.0109104
R-Sq	84.6%	77.40%
P-value (ANOVA)	0.000	0.000
P-value (Factor)		
PCB area(mm.2)	0.001	0.000
Total Comp (SMD)	0.013	-
Total Comp (Manual SMT)	**0.124**	-
Total Comp (Mechanic)	0.001	0.000
Total terminal	0.017	-
Packing	0.041	0.002
VIF (Factor)		
PCB area(mm.2)	3.8	1.7
Total Comp (SMD)	**30.8**	-
Total Comp (Manual SMT)	1.7	-
Total Comp (Mechanic)	3.7	2.5
Total terminal	**32.9**	-
Packing	3.7	1.7

Best subset provided the production estimation equation as in (1) whereas the stepwise gave the equation as in (2). The MAPE analyses found that the time estimating model was defined by (2) providing more precise result as its error was lower and less than 10% (4-9%) which is in the customer acceptable value.

The implementation of (2) for the new product found that the price quoting time was much shorter than the original method, as shown in Table II. The first two steps were the communication with customer. They were routine processes and theirs times were quite constant, averagely. In the third and the fifth steps, the original method spent much longer time as it was found that there were only 3 potential factors affecting to the product, according to (2). In this case, it was not necessary to estimate in all detail of product and its production process. A new design stage was not required as the products were already grouped and only potential time-effect component were required. As the price estimating structure is easier then it is easier to check the quotation at the final stage.

TABLE II
COMPARISON OF PRICE QUOTING METHODS

Quoting Step	Original Method (Hr)	Proposed Method (Hr)
Receive order	2	2
Check data	1	1
Define data	6.5	0.83
Design	1.5	-
Estimate production time	8	0.17
Check Result	2	0.5
Total	21	4.5

By following this research flow, the production time of a specific group of product would be analyzed in the specific form. The price quotation of any product, then, could be performed faster for the company of interest.

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