UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF EARLY ORDER STAGE COST ESTIMATION MODELS FOR SHEET METAL COMPONENTS

MOHAMAD ZAIHIRAIN MOHAMED RASIN

FK 2010 60

DEVELOPMENT OF EARLY ORDER STAGE COST ESTIMATION MODELS FOR SHEET METAL COMPONENTS

By

MOHAMAD ZAIHIRAIN MOHAMED RASIN

© COPYRIGHT UPM

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

November 2010

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

DEVELOPMENT OF EARLY ORDER STAGE COST ESTIMATION MODELS FOR SHEET METAL COMPONENTS

By

MOHAMAD ZAIHIRAIN MOHAMED RASIN

November 2010

Chairman : Associate Professor Datin Napsiah Ismail, PhD

Faculty : Engineering

Timely submission of an accurate cost estimate is vital to the survival of manufacturing support group companies. Late submission of quotation and uncompetitive cost estimate result in lost of customers while an underestimate quotation may reduce company's profit and usually leads to problems later in the production process. Short response time and lack of necessary technical information are the main difficulties frequently faced during the early product cost estimation.

This study develops mathematical models to estimate process cost of sheet metal components at early ordering stage from collection of intuitive cost data and machine operation time. Multivariate statistical analysis is carried out to examine the relative importance of part feature representation extracted from engineering part drawing and to establish the significance relationship between the part features and the unit part process cost. This study introduces a systematic statistical framework for modeling the development of cost estimation for sheet metal components. An analytical classification approach in identifying critical factors is also established.

© COPYRIGHT UPM

The results of analysis illustrate that number of standard holes, bounding box perimeter, inner curved cut-out length, number of sharp edges, number of bend lines and inner straight cut-out length are among the most significant factors that influence the unit part processing cost of sheet metal components. The stability and reliability of the developed models are tested with an independent dataset using Mean Absolute Deviation and Mean Percent Absolute Deviation as main performance indicators.

Cost model developed from machine operation time shows the ability to provide an estimation of part process cost within an acceptable range of 12% accuracy while cost models developed from quoted price shows a more narrowed results within 9.0% accuracy. Both the statistical time-based and price-based models provide a better estimation results compared to estimation cost produced by the company's estimators generated based on their intuitive knowledge and experience.

The statistical quality of the established mathematical models proves that the methodology developed in the study is capable to generate acceptable mathematical models for estimating early part process cost within certain degree of accuracy. The models which utilize parametric techniques provide an acceptable alternative solution to estimate process cost for manufacturing sheet metal components at early order stage in the absence of complete technical part information.

© COPYRIGHT UPM

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PEMBANGUNAN MODEL-MODEL ANGGARAN KOS PERINGKAT AWAL PESANAN UNTUK KOMPONEN-KOMPONEN KEPINGAN LOGAM

Oleh

MOHAMAD ZAIHIRAIN MOHAMED RASIN

November 2010

Pengerusi : Profesor Madya Datin Napsiah Ismail, PhD

Fakulti : Kejuruteraan

Penyerahan satu anggaran kos yang betul tepat pada masanya adalah amat penting bagi kewujudan syarikat-syarikat pengilangan dalam kumpulan sokongan. Penyerahan sebut harga yang lewat dan anggaran kos yang tidak kompetitif akan mengakibatkan kehilangan pelanggan-pelanggan manakala sebut harga di bawah anggaran boleh mengurangkan keuntungan syarikat dan selalunya menuju kepada masalah dalam proses pengeluaran kemudian nanti. Masa balasan yang singkat dan kekurangan maklumat penting teknikal adalah kesukaran-kesukaran utama yang sering dihadapi semasa peringkat awal penganggaran kos produk.

Kajian ini membangunkan model-model matematik untuk menganggar kos proses komponen-komponen kepingan logam pada peringkat awal pesanan daripada koleksi data kos intuitif dan masa pengendalian mesin. Analisis statistik multivariat dijalankan untuk meneliti kepentingan relatif perwakilan ciri barangan yang diekstrak dari lukisan kejuruteraan barangan, dan untuk menubuhkan hubungan bererti diantara ciri-ciri barangan tersebut dan kos proses unit barangan. Kajian ini

© COPYRIGHT UPM

memperkenalkan satu rangka statistik yang sistematik bagi pemodelan pembangunan anggaran kos untuk komponen-komponen kepingan logam. Pendekatan klasifikasi analitis dalam mengenal pasti faktor-faktor kritikal juga didirikan.

Keputusan-keputusan analisis menunjukkan bilangan lubang standard, perimeter kotak sempadan, panjang dalaman potongan melengkung, bilangan sisi, bilangan garisan lipatan dan panjang dalaman potongan lurus adalah antara faktor-faktor paling penting yang mempengaruhi unit kos pemprosesan barangan bagi komponen-komponen kepingan logam. Kestabilan dan kebolehpercayaan model-model yang dibina ini diuji dengan satu set data bebas menggunakan Purata Sisihan Mutlak dan Purata Peratusan Sisihan Mutlak sebagai petunjuk-petunjuk utama prestasi.

Model kos yang dibina daripada masa pengendalian mesin menunjukkan kebolehan untuk menyediakan satu anggaran kos proses barangan dalam lingkungan 12% ketepatan boleh diterima, manakala model kos yang dibina daripada sebutharga menunjukkan keputusan-keputusan yang lebih sempit dalam lingkungan 9% ketepatan. Kedua-dua model statitik berdasarkan masa dan berdasarkan harga menyediakan satu ketepatan anggaran yang lebih baik berbanding dengan kos anggaran yang dikeluarkan oleh pakar atau penganggar syarikat yang dibuat berdasarkan pengetahuan intuitif dan pengalaman mereka.

Kualiti statistik model-model matematik yang didirikan membuktikan metodologi yang dikembangkan dalam kajian ini mampu menghasilkan model-model matematik yang boleh diterima bagi menganggar kos proses barangan awal dalam lingkungan ketepatan tertentu. Model-model ini yang memanfaatkan teknik parametrik

© COPYRIGHT UPM

menyediakan satu penyelesaian alternatif yang boleh diterima untuk menganggar kos proses pembuatan komponen kepingan logam pada peringkat awal tempahan dalam ketiadaan maklumat lengkap teknikal barangan.

© COPYRIGHT UPM

ACKNOWLEDGEMENTS

I wish to express my utmost gratitude and appreciation to my supervisor, Associate Professor Datin Dr. Napsiah Ismail, Faculty of Engineering, Universiti Putra Malaysia, for her persistent guidance, invaluable suggestions and constant encouragement in the successful accomplishment of this thesis. I am also grateful to my supervisory committee members Professor Ir. Dr. Haji Mohd Sapuan Salit and Associate Professor Dr. Wong Shaw Voon for their constructive advice and critical comments towards the completion of this thesis.

My deepest thanks to my family especially to my late father, my mother, wife, sons and daughters, who have always been the nucleus of my constant inspiration, love and motivation, for their utmost understanding, sacrifice and continuous support and encouragement until the completion of this thesis. Thank you all.

© COPYRIGHT UPM

I certify that a Thesis Examination Committee has met on 10 November 2010 to conduct the final examination of Mohamad Zaihirain Bin Mohamed Rasin on his thesis entitled "Development of Early Order Stage Cost Estimation Models for Sheet Metal Components" in accordance with the Universities and University College Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The committee recommends that the student be awarded the Doctor of Philosophy.

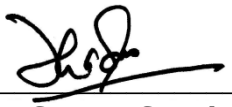
Members of the Thesis Examination Committee were as follows:

Nor Mariah Adam, PEng, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Rosnah Mohd Yusuff , PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Norzima Zulkifli, PhD
Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Mohd Razali Muhamad, PhD
Professor
Universiti Teknikal Malaysia Melaka
Melaka
(External Examiner)



SHAMSUDIN SULAIMAN, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 18 January 2011

© COPYRIGHT UPM

The thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

Datin Napsiah Ismail, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Haji Mohd Sapuan Salit, PEng, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Wong Shaw Voon, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

_____

HASANAH MOHD GHAZALI, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

© COPYRIGHT UPM

DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledge. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

_____

MOHAMAD ZAIHIRAIN MOHAMED RASIN

Date: 10 November 2010

© COPYRIGHT UPM

TABLE OF CONTENTS

		Page
DEDICATIONS		
ABSTRACT		ii
ABSTRAK		iv
ACKNOWLEDGEMENTS		vii
APPROVAL		viii
DECLARATION		x
LIST OF TABLES		xiv
LIST OF FIGURES		xvi
LIST OF ABBREVIATIONS		xx
CHAPTER		
1	**INTRODUCTION**	1
	1.1 Background	1
	1.2 Problem Statement	3
	1.3 Research Objectives	4
	1.4 Scope of the Study	4
	1.5 Thesis Organization	5
2	**LITERATURE REVIEW**	7
	2.1 Cost Estimates in Product Life Cycle	7
	2.2 Magnitude of Cost Estimation	11
	2.3 Difficulties in Cost Estimating	13
	2.4 Product Pricing and Costing	15
	2.4.1 Pricing Objectives	16
	2.4.2 Pricing Methods	18
	2.4.3 Product Costing	19
	2.4.4 Traditional Costing	19
	2.4.5 Activity-Based Costing	20
	2.5 Cost Estimating Techniques	21
	2.5.1 Analytical	23
	2.5.2 Intuitive	23
	2.5.3 Analogical	24
	2.5.4 Parametric	25
	2.6 Cost Estimation Models in Manufacturing	26
	2.7 Commercial Cost Estimating Software Tools	40
	2.8 Multiple Regression for Prediction	44
	2.8.1 The Least-Squares Approach	45
	2.8.2 Statistical Quality of Models	47
	2.8.3 F-test for Statistical Inference	50
	2.8.4 Multicollinearity	51
	2.8.5 Cautions in Applying Multiple Regressions	53
	2.8.6 Sample Size	54
	2.8.7 Detecting Outliers and Influential Observations	54
	2.8.8 Determining Significant Factors	55
	2.8.9 Validating Models	56

© COPYRIGHT UPM

	2.9	Sheet Metal Manufacturing	57
		2.9.1 Sheet Metal Industries	58
		2.9.2 Sheet Metal Process	59
	2.10	Summary	64
3	**METHODOLOGY**		67
	3.1	The Design of a Systematic Statistical Framework	67
		3.1.1 Problem Formulation Stage	70
		3.1.2 Data Collection and Analysis Stage	71
		3.1.3 Model Development Stage	73
		3.1.4 Model Validation Stage	75
	3.2	Problem Formulation	76
	3.3	The Manufacturing Process	79
	3.4	Identifying Influential Factors	83
	3.5	Analytical Classification Approach for Critical Factors	88
	3.6	Data Collection	91
		3.6.1 Extracting Features Information from Part Drawing	92
		3.6.2 Handling Time at CNC Turret Punch Operation	95
		3.6.3 Handling Time at NC Press Brake Operation	97
		3.6.4 Machine Rate And Labor Rate	99
		3.6.5 Generating Process Time and Cost Data	101
		3.6.6 Quoted Price	102
4	**EVALUATION AND VALIDATION**		104
	4.1	Development of Time-Based Model	104
		4.1.1 Descriptive Statistics	104
		4.1.2 Relationship Between Pairs of Variables	108
		4.1.3 Scatterplots	111
		4.1.4 Preliminary Model	115
		4.1.5 Testing for Overall Significance	117
		4.1.6 Multicollinearity Check	118
		4.1.7 Regression and Curve Fitting	121
		4.1.8 Model Validation	128
	4.2	Development of Price-Based Model for Shop B	131
		4.2.1 Descriptive Statistics	132
		4.2.2 Relationships Between Pairs of Variables	133
		4.2.3 Scatterplots	135
		4.2.4 Testing for Overall Significance	136
		4.2.5 Multicollinearity Check	137
		4.2.6 Regression and Curve Fitting	139
		4.2.7 Model Validation	144
	4.3	Development of Price-Based Model for Shop C	147
		4.3.1 Descriptive Statistics	147
		4.3.2 Relationships Between Pairs of Variables	148
		4.3.3 Scatterplots	150
		4.3.4 Testing for Overall Significance	151
		4.3.5 Multicollinearity Check	152
		4.3.6 Regression and Curve Fitting	154
		4.3.7 Model Validation	158

© COPYRIGHT UPM

5	**RESULTS AND DISCUSSION**		161
	5.1	Time-Based Cost Estimation Model	161
	5.2	Price-Based Cost estimation Model for Shop B	164
	5.3	Price-Based Cost estimation Model for Shop C	167
	5.4	Model Comparisons	170
6	**CONCLUSION AND RECOMMENDATIONS**		177
	6.1	Conclusion	177
	6.2	Recommendations for Future Work	180
REFERENCES			182
APPENDICES			
A	Extracted Features Information from Part Drawing		191
B	Machine Time, Handling Time and Unit Process Cost Data		207
C	Quoted Price Data		210
D	Database for Regression Modeling		214
BIODATA OF STUDENT			217
LIST OF PUBLICATIONS			218

© COPYRIGHT UPM