Benefits of Implementing Automated Costing in a Small Machine Shop: A Case Study

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Abstract: Knowledge based cost estimating systems are available, but is there a lower limit to their applicability in an industrial environment? This paper answers this question by examining a knowledge based cost estimating expert system application in a small machine shop. Differences between the traditional experienced-based system currently employed and the automated system are studied. Data is gathered to analyze time effectiveness, accuracy, and payback of the software. Data from seventy part models is recorded to study the time experiment and data from fifty part models is used to study accuracy and consistency.

The results indicate that the software is faster than traditional quoting systems; however, the payback point is high. Also, results show that the software has a smaller average time to manufacture percent difference between the automated system and the actual time to manufacture (TTM) compared to the percentage difference between the traditional TTM and actual TTM. Standard deviation for the automation is also less, implying better consistency. As a result, the attractiveness of the automated system in the limiting case of a small machine shop rests with significantly improved accuracy and consistency rather than payback.

Key Words: Cost Analysis, Automated Costing, Small Machine Shop

1. Introduction

In today's competitive economy, manufacturing companies have to be careful to put money and resources into investments that yield an appropriate return. The applicability of an automated cost estimating system must be based on operational feasibility, and the size of the industrial organization makes a difference to operational viability. As an examination of the lower limit for viability, a small machine shop is examined to try and determine if there is a lower limit to operational viability for a cost estimating system. Here operational viability represents a situation where the benefits outweigh the costs and disbenefits of the automated costing software utilization.

A cost analysis tool can help as one faces decisions that directly affect the cost of goods sold. A bad business decision occurs when the costs to provide a given product or service are under-estimated, and thus a loss occurs. Alternately, when the costs are over-estimated the company is not able to compete in the market. Therefore, accurate cost-estimation is crucial to the success of a company.

This paper reports on a case study that deals with cost-estimation in machine shops and small manufacturing companies. The place where this experiment and data collection takes place is a machine shop located at Matamoros, Mexico named "Maquinados y Proyectos Industriales" (MAQYPROYIND) which in English stands for Machining and Industrial

Projects. Currently, the shop employs eight administrative and technical workers. The shop specializes in traditional machining and automatic (CNC) machining, and has the capacity for fabrication, repair and/or assembly of mold plates, fixtures, shafts, housings, and gears. It also has the capacity to design and manufacture special tooling, if the job necessitates. The shop has the following machine resources: four traditional lathes and one CNC lathe, four traditional turning machines and one CNC, two EDM wire machines, two traditional grinders and one semi-automatic grinder, one industrial oven, two band saws, and other related machine shop equipment. MAQYPROYIND uses a variety of manufacturing processes, including: turning and milling machining, grinding, plastics thermoforming, Electric-Discharge-Machining (EDM), and die-cutting.

The cost-estimation for the shop is performed by two administrative employees. They undergo the following process: (1) study of the part's drawing, usually provided by the client in a CAD model; (2) obtain quotes for raw material price; (3) determine the amount of hours for the part to be manufactured; (4) calculate the part's overhead, obtained by multiplying the machining hours by a calculated factor; and finally, (5) add all the calculated costs plus profit to determine a market price. Material prices are obtained by calling material suppliers, and the time to machine a part is developed based on machining experience.

The cost estimate accuracy completely depends on the experience of the estimators. Today with the accessibility of computer technology, manufacturing companies can benefit in the area of cost estimation utilizing Computer Aided Process Planning (CAPP) systems. SEER-MFG version 6.1 by Galorath Inc is the automated cost system used in this study, and is commercially available.

This study focuses on operational feasibility for automated costing in a small machine shop as the lower limit of industrial activity. First, comparisons are made between automated costing and traditional costing. The goal is to determine a financial payback point. Secondly, the accuracy and consistency of the costing automated methods are compared with traditional costing methods.

This paper presents a case study of a machine shop's cost-estimation process. The process consists of extracting data representing the current method of cost-estimation used in a machine shop and comparing it to data from a commercially developed cost-estimation model. Essentially, an automated cost estimation system requires time and effort to gather the cost data, place the cost data into the automated system, and validate the results. While a completed system may save time and effort, the question answered by this study is whether the effort to commission an automated system is worth the cost for a small business. Stated differently, what is the payback point for the use of an automated costing system in a small manufacturing business? On the other hand, it is considered that once an estimating system is constructed, the estimates determined by the system may be more accurate than estimates produced by traditional estimation; therefore, what is the accuracy of the software compared to the actual manufacturing information and then what is the relationship between the software estimation and the shop's estimation?

In the next section, a literature review is provided. Then, the process of software training and a description of the software employed in this paper are reported along with the experimental methodology. This section is followed by the results of the experiment, and then followed by a discussion. And finally, conclusions are drawn.

2. The Literature

Computer Aided Systems have been increasingly capable of problem solving. A survey of computer systems was completed as a part of this study. Automatic Cost-estimation modeling requires the implementation of a Computer Aided Process Planning (CAPP) system.

Sharma and Gao (2007) developed a knowledge-based model to estimate the cost of a product design/redesign. Zha et al. (2001) developed a knowledge-based system for assembly-oriented design named AODES (Assembly-Oriented Design Expert System). In similar work, Zha and Lin (2000) developed a task planning and simulation system for assembly/disassembly using expert Petri nets. In their research, Shehab and Abdalla (2006) developed a cost-effective knowledge-base for design for automation, which involves: selection of the most economic assembly technique in early design, estimation of the assembly times and costs for manual, automatic and robotic methods. In other work, Cakir and Cavdar (2006) developed a knowledge-based system to solve metal cutting related problems.

As another approach, the case based reasoning is characterized by a mathematical similarity comparison between a source case and a target case. The source cases are historical cases which are stored in a case database, and they contain information relating to problems solved in the past. The target case is a new problem that requests a solution. The most common methods of similarity are the nearest-neighbor retrieval, shown in equation 1, and Euclidian distance.

$$NNR = \frac{\sum_{i=1}^{n} w_i \times Sim(f^I, f^R)}{\sum_{i=1}^{n} w_i} \quad (1)$$

where w_i = weight of feature *i*, and with *Sim* ( ) as a similarity function where f^I and f^R = values of features of the input and retrieve cases.

As one case-based study, Chang et al. (2010) used case-based reasoning to predict the manufacturing cost of a cellular phone. Duverlie and Castelain (1999) used case-based reasoning to determine the best piston for a diesel engine. Ficko et al. (2005) used case-based reasoning to determine the optimal cost function for the manufacturing cost of a stamping tool. Humphreys et al. (2002) used a hybrid system, a knowledge-based system in combination with a case-based system to assist corporation managers in the decision of making or buying a product.

As another popular approach, a multi-agent system employs a number of agents that work toward solving a given problem at the same time. These agents are controlled by a manager that correlates a common ground from all the agent's outputs and thus finds a solution to the problem. Ping (1995) developed a multi-agent system for cost estimation. Other research in this area, Sanders et al. (2009) developed a multi-expert system for design-for-assembly composed of a CAD system, an Automated Assembly System, a Manual Assembly System, and a Design Analysis Expert to manufacture a signature capture device.

Object-oriented approaches are also used. They are characterized by the data extraction of a product's parameters and by the organization of such information into objects. The objects are classified in hierarchies and organized in sequential order. Gayretti and Abdalla (1999) used an object-oriented system to extract the frames and slots data from a 3D solid model in the process of a product's development. In a similar manner, Fisher and Koch (1994) developed a CAD-system with an expert system shell that also uses an object-oriented approach for product development. Also, Bramall et al. (2003) used an object-oriented process planner to investigate the manufacturability of a solid-state power amplifier chassis.

Other work has focused on Concurrent Engineering. Concurrent Engineering is an important tool for product development; therefore, expert systems have been explored in this area. Shehab and Abdalla (2001) developed a cost modeling system for product development using Concurrent Engineering.

Another area of manufacturing engineering that has been explored with expert systems is assembly optimization. Daabub and Abdalla (1999) used an expert system to reduce total production cost focused on DFA (Design for Assembly). Also, Zha et al. (2001) developed a knowledge-based system for assembly-oriented design named AODES (Assembly-Oriented Design Expert System). Zha and Lin (2000) developed a task planning and simulation system for assembly/disassembly using expert Petri nets. In a similar manner, Sanders et al. (2009) developed a multi-expert system for design-for-assembly.

Computer Aided Process Planning (CAPP) is an automated technique for the planning of a product's manufacturing process that can be developed using expert system technology. Sood and Wright (1993) mentions the following list of published CAPP systems: APPAS, CADCAM, CAPP, CMMP, CAPPSY, AUTAP, COBAPP, AUTOPLAN, AACHEN, AUTOCAP, GENPLAN, GARI, TOM, ACAPS, MIPLAN, CMPP, PROPLAN, DCLASS, EXPSS-E, CUTTECH, HI-MAPP, AMRF, XCUT, SIPS, MACHINIST, and NEXT-CUT.

Given the importance of cost estimation in manufacturing job bidding, cost estimation is a field that has been well investigated. Garcia and Crespo (2009) surveyed machining price quotation methods that involve both traditional and automated methods: automated (expert systems) and non-automated (conventional costing methods). More models are surveyed in Shehab and Abdalla (2001) involving cost estimation. Others are surveyed in Gonzalez's (2012) thesis.

In a cost-estimation system, Duverlie and Castelain (1999) used case-based reasoning methods to determine the best estimation of cost of a piston. In a similar manner, Needy et al. (1998) developed a cost model for cellular manufacturing. In other work, Koltai et al. (2000) developed a system that allocated costs in flexible manufacturing systems (FMS). Similarly, Culler and Burd (2007) integrate manufacturing processes. In other works, Ping (1995) developed a multi-agent system for cost estimation, Sharma and Gao (2007) developed a knowledge-based model to estimate the cost of a product design/redesign, and Kingsman and Souza (1997) developed a knowledge-based system for cost-estimation and pricing decisions in made-to-order manufacturing. Clearly, cost estimation with intelligent systems has been well investigated.

There is plenty of information about the incorporation of computer technology into manufacturing processes and administration that manufacturing companies can utilize to improve performance. However, there is no information of the cost absorbed by a company to employ a cost-estimation expert system and how such a system may be of assistance to the company.

3. Software and Methods

For a comparison of MAQYPROYIND's traditional estimation system with a computer based estimation system, SEER for Manufacturing (SEER-MFG) version 6.1 was employed. To create an estimate in SEER-MFG, a new project file is started. Then, work elements are defined into parts, assemblies, or process steps. Finally, parameters are entered in the Parameters Window. See Figure 1. Once the parameters are considered in the estimation, the SEER automated system reports labor cost, additional costs, and additional data. Labor cost includes: setup, direct, inspection, and rework costs; additional costs includes: material, vendor, tooling, and other costs; and additional data includes: manufacturing index, raw weight, finished weight, mean-time between failures (MTBF), and mean time to repair (MTTR).

The cost-estimation software works in parent-to-child hierarchies called Work Elements as it is shown in top-left sub window of Figure 1; therefore, the overall project to be estimated can include a different number of part models that form one assembly, or just one part model. A combination of child manufacturing process elements can be amalgamated with a parent Work Element called a Roll-up. The top-left part of Figure 2 shows Rollup 1.1 JG10A109, which is a part model number, with child 1.1.1 machining operations, which is a machining work element, and 1.1.2 clear anodize, which is a finish & heat treat work element. Each Work Element type has a set of parameters that can be manually inserted from known process information to integrated mathematical equations or automatically inserted by using a template from the knowledge database. The bottom-part of Figure 2 shows the Create/Modify Work Element window where the manufacturing process type and the knowledge base template are chosen, if applicable.

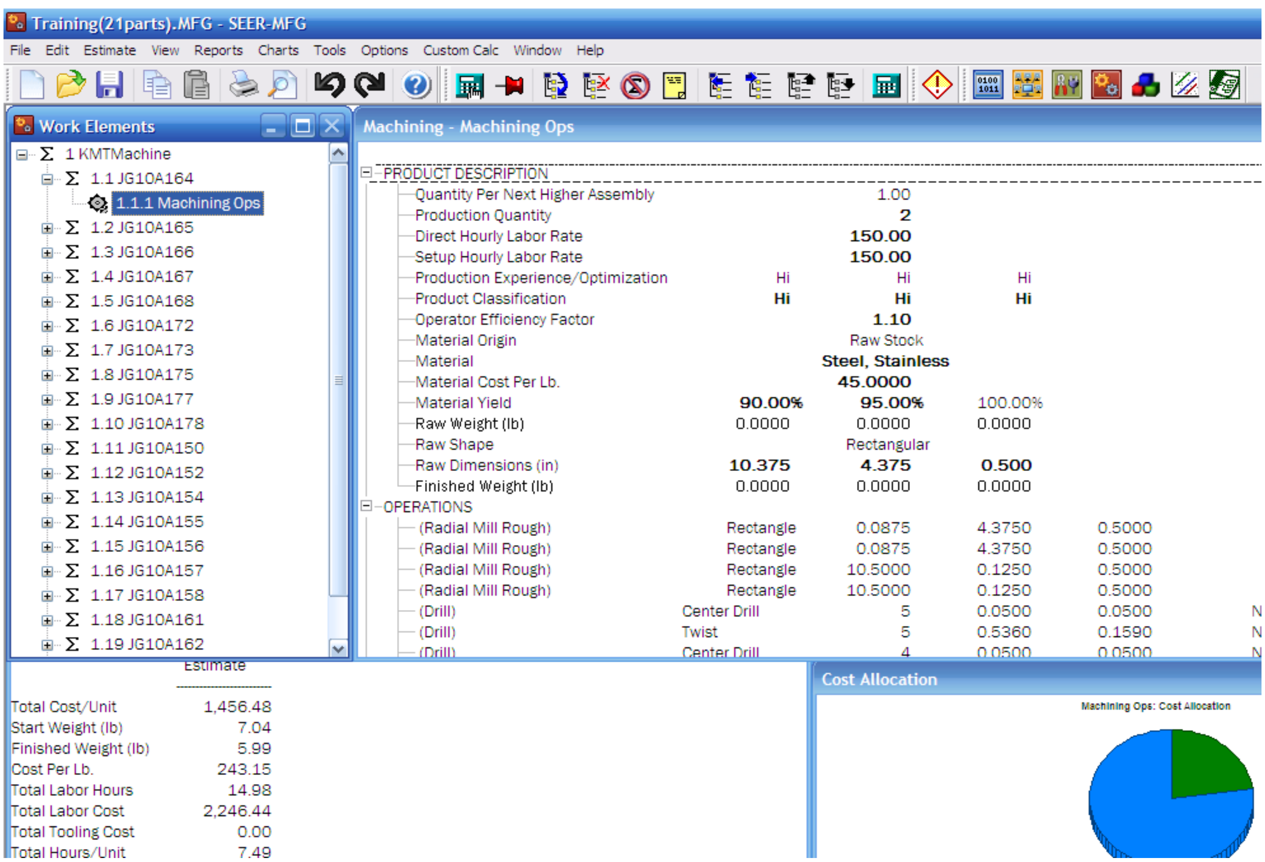


Figure 1: Schematic of the Work Elements (sub-window on top-left).

Figure 3 shows the Machining Work Element parameters. The category labels of parameters for the Machining element are: Product Description, Operations, Manufacturing Description, Optional Cost Description, Tool Description, Inspection, Rework, Marking, Packaging, Labor Calibration, Probability (Risk), Part Assembly Contribution, and Financial Factors, as shown in Figure 2.

3.1 Training with the Automated System

The training provided consisted of five hours of one-on-one coaching via web conferencing. The training sessions covered an overall review of the software, its capabilities, and how to model a machine shop using it. Also, the training included the analysis of real parts.

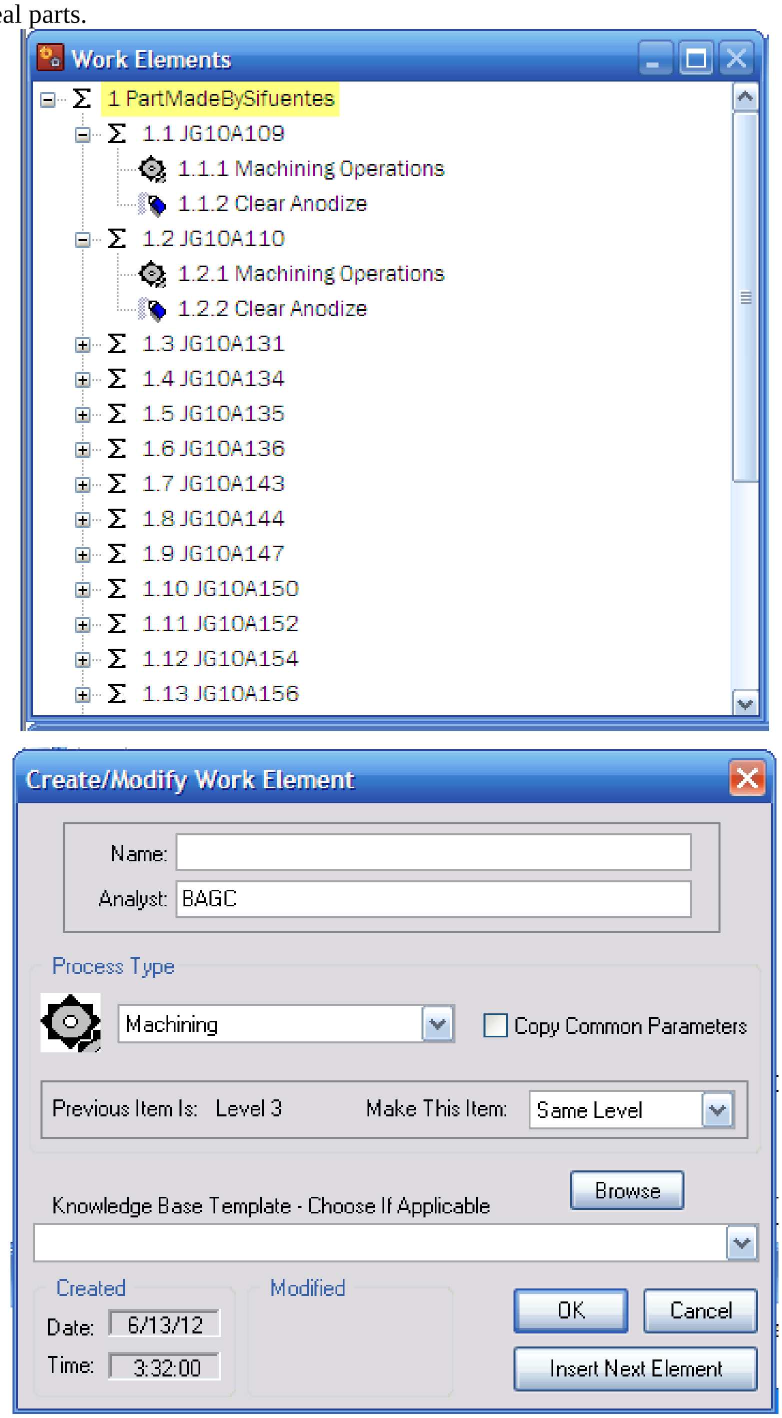
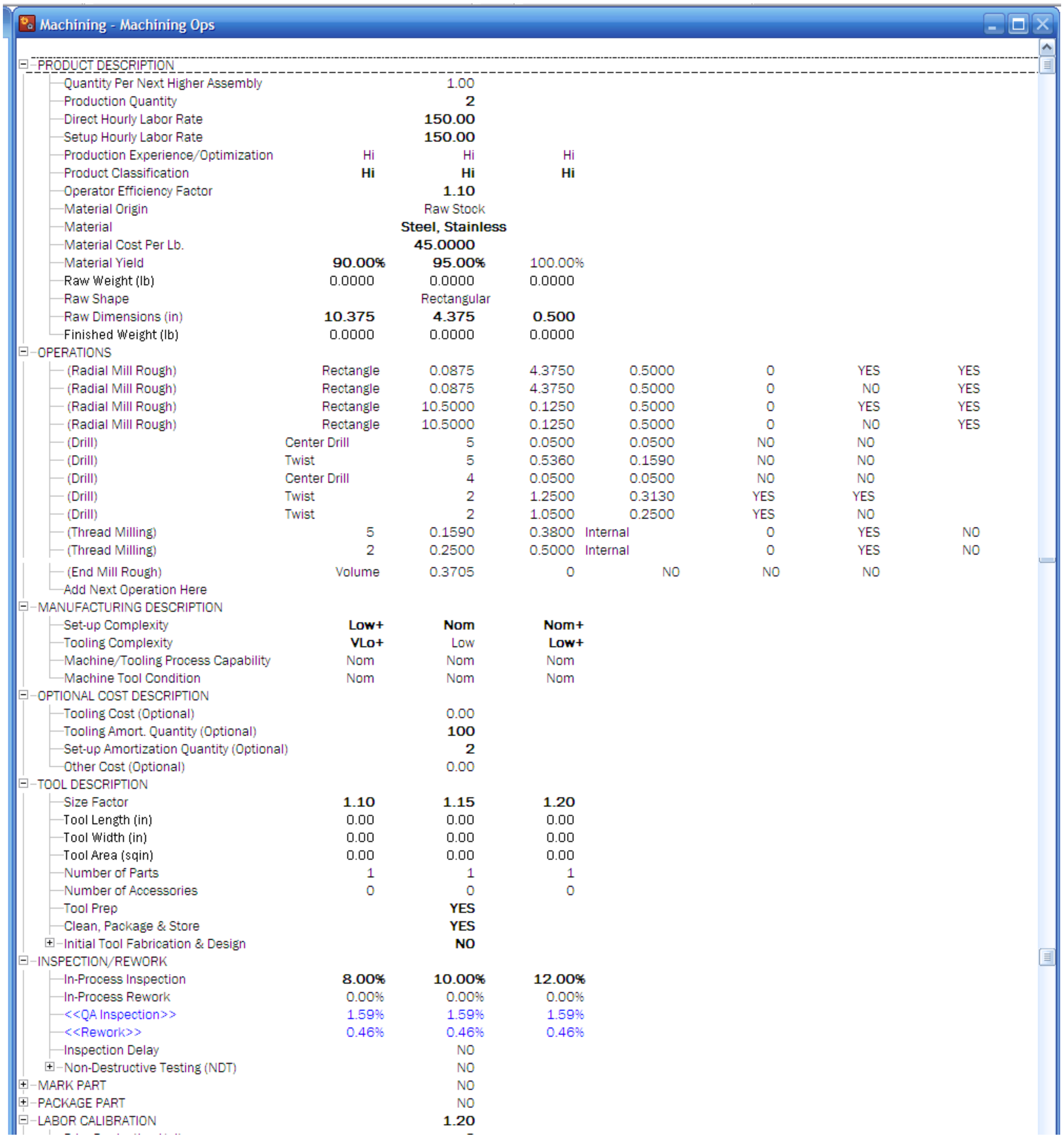


Figure 2: Schematic of Rollup Work Element.



Machining - Machining Ops

PRODUCT DESCRIPTION							
Quantity Per Next Higher Assembly		1.00					
Production Quantity		**2**					
Direct Hourly Labor Rate		**150.00**					
Setup Hourly Labor Rate		**150.00**					
Production Experience/Optimization	Hi	Hi	Hi				
Product Classification	**Hi**	**Hi**	**Hi**				
Operator Efficiency Factor		**1.10**					
Material Origin		Raw Stock					
Material		**Steel, Stainless**					
Material Cost Per Lb.		**45.0000**					
Material Yield	**90.00%**	**95.00%**	100.00%				
Raw Weight (lb)	0.0000	0.0000	0.0000				
Raw Shape		Rectangular					
Raw Dimensions (in)	**10.375**	**4.375**	**0.500**				
Finished Weight (lb)	0.0000	0.0000	0.0000				
OPERATIONS							
(Radial Mill Rough)	Rectangle	0.0875	4.3750	0.5000	0	YES	YES
(Radial Mill Rough)	Rectangle	0.0875	4.3750	0.5000	0	NO	YES
(Radial Mill Rough)	Rectangle	10.5000	0.1250	0.5000	0	YES	YES
(Radial Mill Rough)	Rectangle	10.5000	0.1250	0.5000	0	NO	YES
(Drill)	Center Drill	5	0.0500	0.0500	NO	NO	
(Drill)	Twist	5	0.5360	0.1590	NO	NO	
(Drill)	Center Drill	4	0.0500	0.0500	NO	NO	
(Drill)	Twist	2	1.2500	0.3130	YES	YES	
(Drill)	Twist	2	1.0500	0.2500	YES	NO	
(Thread Milling)	5	0.1590	0.3800	Internal	0	YES	NO
(Thread Milling)	2	0.2500	0.5000	Internal	0	YES	NO
(End Mill Rough)	Volume	0.3705	0	NO	NO	NO	
Add Next Operation Here							
MANUFACTURING DESCRIPTION							
Set-up Complexity	**Low+**	**Nom**	**Nom+**				
Tooling Complexity	**VLo+**	Low	**Low+**				
Machine/Tooling Process Capability	Nom	Nom	Nom				
Machine Tool Condition	Nom	Nom	Nom				
OPTIONAL COST DESCRIPTION							
Tooling Cost (Optional)		0.00					
Tooling Amort. Quantity (Optional)		**100**					
Set-up Amortization Quantity (Optional)		**2**					
Other Cost (Optional)		0.00					
TOOL DESCRIPTION							
Size Factor	**1.10**	**1.15**	**1.20**				
Tool Length (in)	0.00	0.00	0.00				
Tool Width (in)	0.00	0.00	0.00				
Tool Area (sqin)	0.00	0.00	0.00				
Number of Parts	1	1	1				
Number of Accessories	0	0	0				
Tool Prep		**YES**					
Clean, Package & Store		**YES**					
Initial Tool Fabrication & Design		**NO**					
INSPECTION/REWORK							
In-Process Inspection	**8.00%**	**10.00%**	**12.00%**				
In-Process Rework	0.00%	0.00%	0.00%				
<<QA Inspection>>	1.59%	1.59%	1.59%				
<<Rework>>	0.46%	0.46%	0.46%				
Inspection Delay		NO					
Non-Destructive Testing (NDT)		NO					
MARK PART		NO					
PACKAGE PART		NO					
LABOR CALIBRATION		**1.20**					

Figure 3: Machining Work Element Parameters Window.

Twenty three part models were quoted with times to quote documented. The first two parts were completed for presentation to the trainer, so that they could be evaluated and corrected by him; the remaining 21 part estimates were completed utilizing recommendations given. Figure 4 shows a part number vs. time-to-quote relation that was obtained in the training. The plot shows learning as it relates to the quotation experience. The first quotes took hours to produce. As more quotes were completed, the learning approaches 12.3 minutes for the last fourteen part models. The total number of training hours was 27.08, which included web conference training, practice models, and time for software manual reading.

The data was gathered by four different individuals: the traditional system's estimations and the actual Time-to-Manufacture (TTM) were provided by two of MAQYPROYIND's technicians and one administrator, and the automated system estimates were modeled and collected by the first author.

The traditional quoting system vs. the automated system analysis is an analysis between the time that it takes a MAQYPROYIND employee to quote a part model and the time it takes for the automated system to quote the same part. This relationship is important because it determines the time effectiveness of the computer system compared to the traditional system. If the cost estimation process becomes faster, then the cost involved in estimation is reduced. This analysis is also used to determine the payback period of the investment in software and training. In order to determine the time efficiency, both quoting methods use the same part models.

Seventy part models, provided by a customer of MAQYPROYIND for bidding, were used in this part of the experiment. All of the parts are made of steel and require electroless nickel plating for surface finishing. Together, they assemble a semi-automatic industrial machine; however, the assembly is to be done by the customer, and assembly labor is not considered in the quotation.

Seventy part models were given to a technician with special instructions. They were asked to quote all the parts and to provide an estimate that includes the following information: material cost estimation in Mexican pesos, Time-to-Manufacture (TTM) in hours, cost per part in pesos, and the time to quote in minutes per part.

The semi-automatic industrial machine part models were quoted by the first author using the automated system. As a demonstration, the procedures of estimating cost using the automated system are explained in this section using part model 0001 as an example. Figure 5 is a drawing of part model 0001.

An online chronometer is used for this experiment. The time clock is started before the creation of the part model's work element and stopped at the entry of the last parameter. The time is recorded in minutes.

3.2 Actual TTM vs. the Automated System's TTM

The Actual TTM vs. the automated system's TTM analysis is the study between the real time-to-manufacture and the time-to-manufacture developed by the automated system for fifty part models. This analysis is important in that it determines the accuracy of the computer system compared to the performance of the machine shop personnel. In order to accomplish this comparison, MAQYPROYIND's historical parts, which have the TTM recorded, are collected.

Fifty historical part models were collected for this analysis. These parts are made of a variety of materials, have different sizes and machinability, and belong to more than one customer and project. Some of the parts form an assembly for a surface finishing semi-automatic machine; others are just spare part orders.

The actual TTM of the 50 part models was recorded by the machinists. They were instructed to record the amount of time that it takes to machine a part on the part drawing and to archive it. When the quantity of the parts is more than one, the total hours of machining time are recorded together with the total quantity. The TTM used in this experiment for part quantities greater than one is the total TTM over the quantity. The 50 part models are estimated in the automated system in the same manner as described earlier.

The relationship between traditional and the automated system time-to-quote and the relationship between the automated system and actual time-to-manufacture (TTM) have been discussed; however, there are two more studies presented in this paper: the relationship between the estimated TTM and the actual TTM and the relationship between the estimated TTM and the automated system's TTM. These last two relationships are important in that the former evaluates the current traditional quoting system that the machine shop uses, and the latter determines how different the two quoting methods are from each other. Additional detail is provided by Gonzalez (2012).

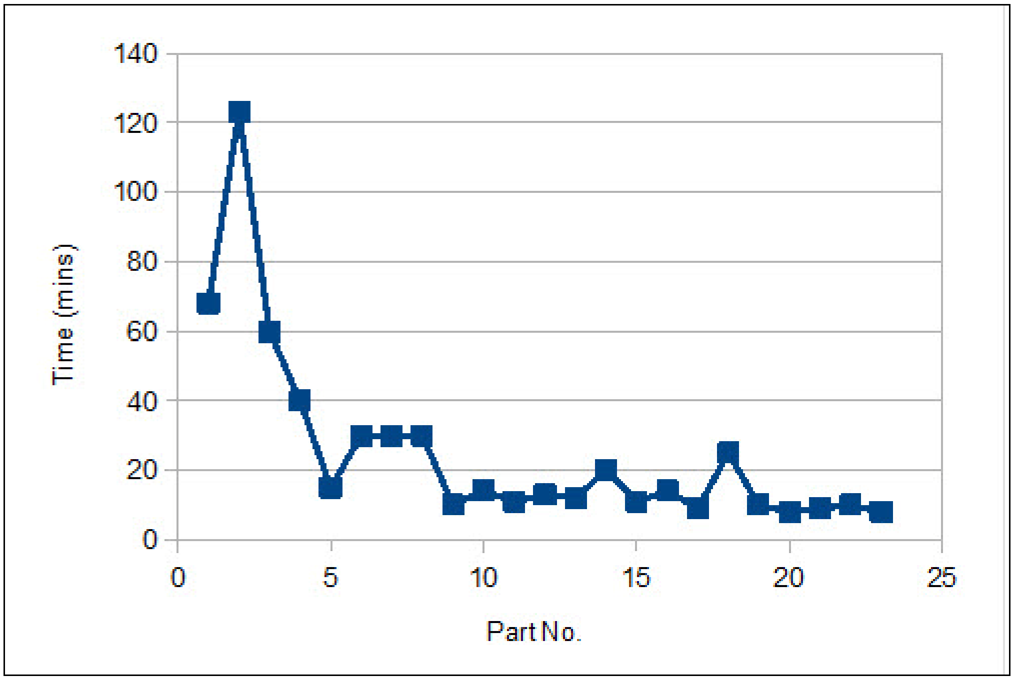


Figure 4: Plot of Part Number vs. Time-To-Quote.

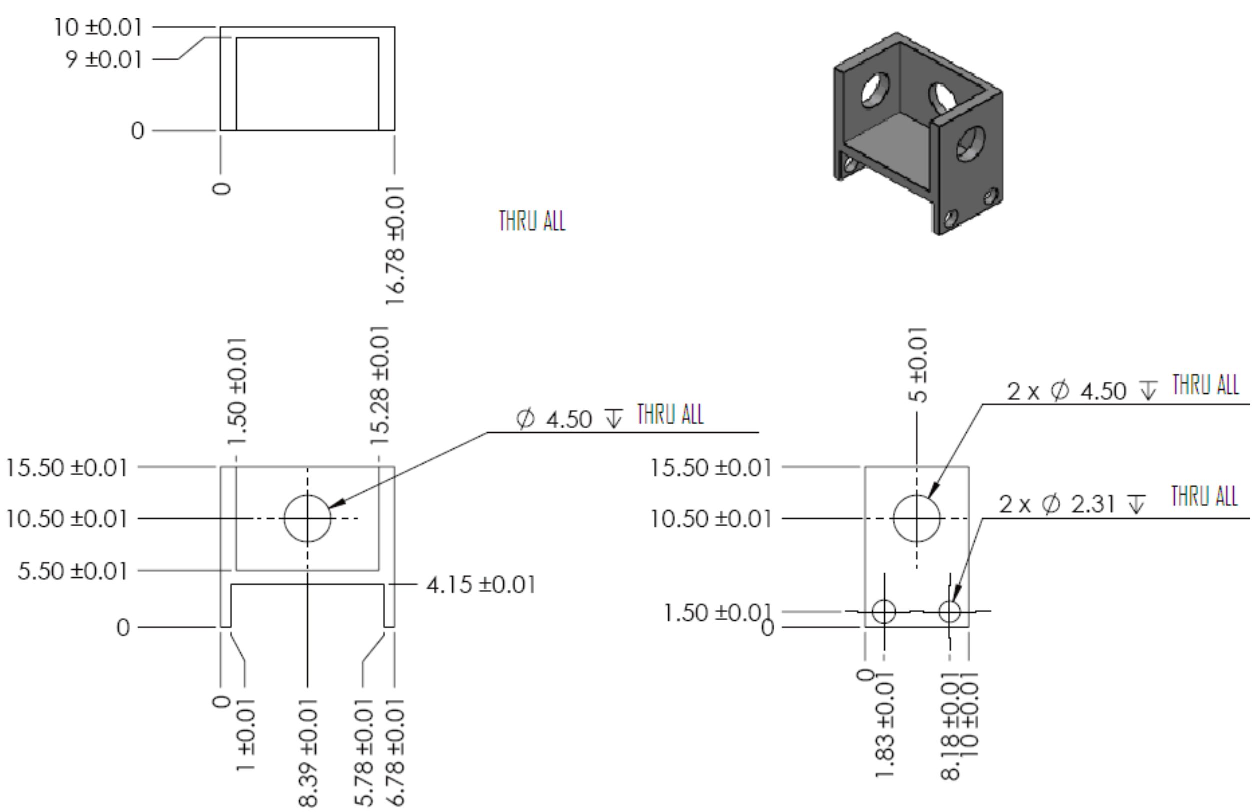


Figure 5: Part Model 0001.

4. Results

This section reports the results for the analysis done to determine the time-efficiency and accuracy. It also compares TTM between traditional and computer estimation systems and the actual TTM.

4.1 Timing Experiment

As mentioned, the traditional vs. the automated system analysis determines which of the systems is more efficient in quickly completing a quote. To determine this, 70 part models were quoted and timed for both a traditional, human prepared quote and a quote prepared with the automated system. Using a spreadsheet, the percentage differences are calculated per part and averaged. The percentage was obtained by subtracting the traditional time-to-quote to the automated system's time-to-quote and divide it by the traditional time-to-quote for each part model involved and then taking the average of these differences. The results of the time efficiency case study indicate that the cost-estimating computer system is quicker than the traditional cost-estimating system. The difference percentage average is 10.2% for the 70 part models analyzed, and it is positive, which suggests that the traditional time-to-quote is greater by 10.2%. Descriptive statistics for these samples are found in Table 1.

It is important to determine whether the mean of the time-efficiency experiment is significantly different on a statistical basis. In order to determine this, a paired t-test of hypothesis is employed on the data gathered. The results show that the p value is 0.016, and with a confidence level of 95%, the null hypothesis that the means are equal can be rejected. Thus, the difference is significant at the 95% confidence level.

4.2 Accuracy Experiment

In order to determine the accuracy of MAQYPROYIND's current cost-estimation system and the automated system's cost-estimation system times-to-manufacture, both methods are studied and compared to actual TTM. Fifty part models are used in this analysis. Estimated TTM, the automated system's TTM, and actual TTM are recorded on a spreadsheet and analyzed.

Table 1 – Descriptive Statistics for Time to Quote

	Traditional Quote	Automated Quotation
Sample Mean	6.686	5.791
Sample Standard Deviation	3.169	3.651
Quantity in Sample	70	70
Sample Minimum	2	0.8
Sample Maximum	20	23.9

The results for the traditional TTM vs. actual TTM indicate that traditional method of cost-estimating is 152% more lengthy than the actual times-to-manufacture. Out of these differences, most are over-estimated. This analysis shows that there is a risk for the machine shop that may cause the loss of biddings against the competition in the market because of over-estimation of projects. Descriptive statistics for these samples are found in Table 2.

A paired t-test of hypothesis is performed to determine if there is a statistically significant difference between the traditional TTM and the actual TTM. The results of the test show a p-value of 0, and there is a statistically significant difference between the traditional TTM and the actual TTM at the 95% confidence level.

As the other part of the accuracy experiment, the analysis suggests that the estimates of the computer system differ by 22.3% from the actual historical records. The percentage difference was determined. Because the percentage difference uses the absolute value of the difference between the automated system's TTM and actuals TTM; however, if the absolute value is removed from the equation and allowed for the negative and positive values to cancel one another, the sum of these differences is negative. This suggests that the estimation of the automated system's TTM manufacture is less than the actual TTM most of the time. Descriptive statistics for these samples are found in Table 3.

A paired t-test of hypothesis is also performed to show if there is a statistically significant difference between the automated system TTM and the actual TTM. The results of the test show a p value of 0.064; therefore, the null hypothesis cannot be rejected at the 95% confidence level and it can be stated that there is not a statistically significant difference between the automated system's TTM and the actual TTM. In other words, the automated system's TTM is statistically equal to actual TTM.

Table 2 – Descriptive Statistics for Accuracy

	Traditional Quote	Actual Time
Sample Mean	3.646	2.057
Sample Standard Deviation	2.737	1.619
Quantity in Sample	50	50
Sample Minimum	0.43	0.33
Sample Maximum	10.85	8.25

Table 3 – Descriptive Statistics for Accuracy

	Automated Quote	Actual Time
Sample Mean	1.837	2.057
Sample Standard Deviation	1.251	1.619
Quantity in Sample	50	50
Sample Minimum	0.28	0.33
Sample Maximum	5.83	8.25

4.3 Variability

In order to study the consistency of the traditional cost-estimation method and the automated cost-estimation method, the variability of the data collected is considered. The variance of the difference between the traditional TTM and the actual TTM, together with the variance of the difference between the automated TTM and the actual TTM, are developed. The variance of traditional vs. actual TTM's is about four and a half hours. The variance of the automated system vs. actual TTM is about half an hour. The results of the variability analysis suggest that the automated cost-estimation method has a greater consistency when compared to the traditional cost-estimation method; therefore, the automated system allows MAQYPROYIND to have more control of risk in cost estimating.

In order to test if the difference of the variances discussed in the last section is statistically significant, a hypothesis test on the ratio of the two variances is performed. Montgomery and Runger's (2006) method is used. The null hypothesis states that the variance of traditional vs. actual TTM is equal to the variance of the automated system vs. actual TTM.

With a confidence of 95% and degrees of freedom of 49, the lower limit and the upper limit is 0.567 and 1.762, respectively. The test statistic is 9.22. Since the test statistic value is out of the limit range, the null hypothesis can be rejected. In other words, there is a significant difference in the consistency between the traditional system and the automated system. Now that the means and standard deviations of the corresponding case studies have been reported and analyzed with consideration of its significance, some important statements follow in the next section.

5. Discussion

Since the automated cost-estimation system has an advantage over the traditional system by 10.2%, the payback analysis can be completed. The other factors necessary to calculate the payback period are the fixed costs of the software investment and the variable costs as time saved per part estimated. The fixed costs factors include: cost of software and cost of training, and the variable costs factors include the: time-efficiency factor, average time-to-quote traditionally, and labor cost rate. The results of the break-even indicate that 46,970 parts to quote per year is the point to recover costs invested in employing automated cost-estimation software. For a small machine shop, this is a very large number of parts per year! Software cost and labor cost rates are not provided to protect MAQYPROYIND's proprietary information.

In the present economy, the investment of money must be done with caution and extra effort is necessary to accomplish a return of investment and to stay competitive. Cost-estimation is the foundation of business effectiveness, especially in manufacturing, since the capacity of a company to remain in the market and the ability to generate revenue depend on it. Small manufacturing companies seem to have cost-estimation difficulties that are different than large manufacturing companies. Some examples of these difficulties are quoting new products in a constant basis and relying mainly on machining experience to determine the cost of manufacturing. Without a strong base in a cost-estimation system, a manufacturing company may lose money if estimations are under the actual cost and may lose biddings if estimations are over the actual cost. Both of these eventualities pose significant threats to the on-going existence of the business, so accuracy is important. The results show accuracy by the automated system compared to traditional methods is superior. Also, the automated system is also proved to be more consistent.

6. Conclusions

In order to prepare for the software implementation in the machine shop, product orientation was provided by an expert in the software rather than a formal training course and doing practice estimations using part models that MAQYPROYIND had in its archives. Training was continued until the time-to-quote learning curve reached a fixed point. The total training time was 27.08 hours and the time-to-quote for the practice models reached an average of 12.3 minutes for the last fourteen part models used. Once training was accomplished, the process to gather experimental data began. The data involving the traditional aspect was gathered by two machinist and quoting experts, and the data involving the automated system was gathered by the first author. The data was gathered to analyze time-effectiveness, payback, and accuracy of the software implementation in the shop. Data from seventy part models was recorded to study the time-effectiveness and payback, and data from fifty part models was used to study the accuracy. The data was analyzed by using basic statistics.

The results indicated that the software was 10.2% faster that the traditional quoting system in this case study; however, the payback point was still high at 46,970 parts. Also, the results showed that the difference between the software TTM and actual TTM was statistically insignificant while the difference between the traditional and actual TTM's was statistically significant and 152%. This difference in accuracy is a justification to invest in the automated system. Also, the variability analysis showed that the automated system has greater consistency than the traditional cost-estimation method. The variance of the difference between the traditional and actual TTM was of 4.52 hours, and the variance of the difference between the automated and actual TTM was of 0.49 hours. The variances were tested using test of hypothesis, and the results showed that there is a statistical difference. This difference between variances is also a justification for MAQYPROYIND to invest in the implementation of the automated cost-estimation method.

By using an automated cost-estimation system in the small machine shop, quotes can be generated 10.2% faster, but that is not a significant factor. What is significant is that substantially better accuracy, repeatability, and consistency can be achieved. This consideration represents an important characteristic that can dramatically help the small machine shop to remain competitive in a global economy. As a result of this case study, the lower limit for automated cost estimating in an industrial organization has been established. The automated cost estimating system justifies itself at the lower limit of industrial activity.

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