Cost Issues in Software Engineering

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ABSTRACT
Software cost estimation (SCE) is a process of predicting efforts and costs in terms of money, time and staff for each software.

One of the problems with estimating software costs is the evaluation of estimation models. Practitioners have been concerned to appreciate for their inability the costs associated with software development accurately. This concern has become more urgent as the problems associated with development costs continue to increase. Consequently, considerable research attention is now directed to provide a complete understanding of the software development process and the preparation and evaluation of software cost estimating tools. Many estimation models have been proposed in the last twenty to thirty years. Many software companies track and analyse project performance by measuring the accuracy of cost estimation. A number of measures are reported in the literature, but have deficiencies. There is no widely accepted standard for assessing estimation models and existing measures are sometimes inconsistent with each other. We also show the surveys indicate that the mean absolute error percentage (MAPE) is the most widely used measure of prediction accuracy in companies and organizations. However, it is skewed.

Models of estimation are usually analysed against two attributes: precision of the estimation of coherence and its consistency. This article examines existing measures for estimating accuracy and consistency, and proposes two new methods: weighted mean quartile relative error (WMQ) as a measure of the accuracy and standard deviation of the proportions of the estimates of the actual observation (SDR) as a measure of consistency. A new criterion has also been proposed to determine the parameters of the regression model. In this paper, we also evaluated five of the most popular methods used to estimate software costs (historical analogy, expert judgment, Delphi method, algorithmic approach and bottom-up approximation). We investigate an alternative relative measure of precision, which avoids MAPE bias: the hit ratio protocol: log (forecast / real). Experience shows that dynamic neural and based techniques are less mature than other kinds of techniques, but that all kinds of techniques are challenged by the rapid pace of change in software technology.

General Terms
Cost Issues, Root Mean of Squares of Error(RMSE), Weighed Mean Quartiles(WMQ), Source Lines of Code(SLOC) algorithm, Coefficient of estimates and actual values(SDR), Mean of Absolute Errors(MAE), Mean (or Average) of Relative Errors(ARE), Mean of Magnitude of Relative Errors(MRE).

Keywords
Cost estimation, Cost Issues, Software Engineering, Weighed Mean Quartiles(WMQ), Root Mean of Squares of Error(RMSE), SLOC algorithm, Delphi approach, Bottom-up approach.

1. INTRODUCTION
Since the early 1950s, software developers and researchers have attempted to develop methods for estimating software costs and schedules (Abdel-Hamid, 1990). Cost estimating software models in the literature that appeared in the last two decades (Wrigley et al., 1991). However, the field of estimating software costs is still in its infancy. (Kitchenham et al., 1990). Existing cost estimation methods are far from standardized and reliable (Rowlands, 1989). It is necessary to evaluate the estimation models and to improve the modelling processes. In this paper, we deal with the quantitative evaluation of the software models that it costs. A new approach is also proposed for the determination of model parameters. The first part examines measures for the evaluation of estimation models. To overcome the shortcomings of existing practices, two new measures are proposed: the weighted mean of the relative error (WMQ) that provide precision measurement and the standard deviation of the proportions of the real value estimate (SDR), which provides a measure of consistency. The second part examines traditional mathematical methods for the formulation of price models and proposes a new regression test, which is called the smallest sum of the logarithmic ratios of the estimated value to the actual value. This is an unbiased method to find the parameters of a cost estimation model, when the functional form of the model is known. The third part evaluates the proposed measures and the criterion.

Boehm in his paper examines eight models (including COCOMO) in his review. They are (1) SDC, (2) Wolverton, (3) SLIM, (4) Doty, (5) PRICE, (6) IBM FSD, (7) Boeing and (8) COCOMO. After reviewing the list of candidates, a review of the most recent editions of the Journal of Parametric was conducted to determine the popularity of these models, as evidenced by their inclusion in other research. The PRICE model is also very popular, but it has been specially designed for use in aerospace applications and therefore was for business applications that would include the database, considered inappropriate.

The purpose of the software cost estimate is:

a) The budget: Define the resources that are needed to produce the software product to test and validate and manage these activities.
b) Software Quality
c) Trade-off and risk analysis. So it is practical to quantify the uncertainty and risk inherent in this estimate.

d) Test bed development.
e) Development Environment Support
f) Software system level test support including modelling and simulation
g) Administrative and support costs
h) Independent Verification and Validation (IV and V).
i) Other audit or honorary support.
j) Investment Analysis Improvement Software.

A detailed cost estimate is important because:

a) Assistance for the classification and prioritization of development projects in terms of a general plan.
b) It is used to determine which resources are committed to the project and how well those resources are used.
c) It is used to assess the impact of changes and support re-planning.
d) Projects can be easier to manage and control when resources are better adapted to actual needs.

The need for the empirical validation of various predictive software expenditure systems has been so competitive that it has led to hundreds of studies to be conducted. However, there remains a lack of synthesized findings. So, to our knowledge, this study is the first systematic comparison of empirical data from two competitor forecasting systems.

If the accuracy of a prediction is to be measured then the relative magnitude of the relative error (MRE) is used in which the absolute value of the ratio between the error and the actual value is observed: │(real-predicted) / real│ or │(y - ŷ) / y│. When multiplied by 100, the absolute error in percent (APE) is obtained. This measure is generally used only when the amount of interest is strictly positive, and we will at all times assume so in this paper. In assessing the accuracy of the multiple predictions a form of aggregation is required. If we take the arithmetic mean, then we will use the mean absolute percentage error, MAPE. In some disciplines, this is known as the "Mean Magnitude of Relative Errors" (MMRE). According to a number of peer-reviewed Gneiting (2011) surveys, MAPE is the most widely used measure to evaluate predictions in organizations.

According to Kolassa and Martin (2011), a major problem that has not received enough attention with respect to MAPE is that when it is used as a basis to compare different methods or systems, the MAPE comparatively rewards methods that systematically underestimate. We have focused on this problem, explaining why it happens, and suggest an alternative measure of accuracy. We consider its use for model selection and use in parameter prediction models.

The formula for MAPE is not symmetric in the sense that exchange y and ŷ do not lead to the same response even though the absolute error is the same before and after the switch. The cause of this asymmetry is in the denominator of the formula: division by the predicted value and instead of the real one and leads to a different result.

2. ACCURACY MEASURES

Precision is defined as the measure of how close it is to the result of the correct value (Deeson, 1991). There are two ways to compare a result and the right value: their ratio and their difference. Let n be the number of projects in a record, let actual value for a ith project be acti (i=1,2,...,n) and predicted value for that project be esti (i=1,2,...n). Difference measure is the difference between the two values for each project. [38] The ratio measure is the ratio of predicted value to the real value for each project.

Difference Measures (Accuracy)

1.) Mean of absolute errors (MAE)
2.) Root mean of squares of error (RMSE)
3.) Coefficient of determinant (R^2)
4.) Mean of residues (MR)

Ratio Measures (Accuracy)

1.) Mean (or average) of relative errors (ARE)
2.) Mean of magnitude of relative errors (MRE)
3.) Root mean of squared relative errors (RMSRE)
4.) Prediction at level *l* (PRED(*l*))
5.) Third quartile of mre (Q3)

2.1 The Fitting accuracy

It is defined as how efficiently a model fits the data that has been generated. To evaluate the accuracy of fit, R is a good measure. The definition of R clearly states that it is related to the variance of the observed values. Due to higher variation, it is easier to get a large R. R measures the proportion of the variation in the dependent variable that is explained by the regression equation. The higher the R value is, the greater the explanatory power of the regression equation. When R is close to 0, then either the functional form of the model does not match the dataset from which it was generated, or more independent variables are required to explain in more detail the variation in the dependent variable.

2.2 The Prediction Accuracy

It is the precision of the efficiency of a prediction from the model. To assess the accuracy of the prediction, the difference measures are inadequate. As for the estimation of software costs, the prediction error increases with the amplitude of the observed value. The larger the project, the harder it is to estimate the effort. Difference measurements are not adequate if they are used for both large and small projects because they do not take into account the size of the projects. Therefore, difference measures should not be used to assess the accuracy of forecasts, as they penalize forecasting for large projects. On the other hand, the relative error is a prediction error in each unit of average effort, reflects the "error rate". It takes into account the scope of the project and allows greater absolute error for large projects. Therefore, the ratio measure is more appropriate for the assessment of accuracy in estimating software costs.

2.3 A Proposed Measure of Precision - Weighted Mean Quartiles (WMQ)

To solve the identified problems, it is proposed to use the weighted mean of quartiles (WMQ) of the MRE when measuring the accuracy of the prediction. The third quartile (Q3) is the most significant one as 75% of mre's values are less than it. So it is weighted with 75. The second quartile (Q2) is weighted with 50, and the first quartile (Q,) is weighted with 25. The WMQ is defined as:

WMQ= (25Q1 + 50Q2 + 75Q3)/150.

There are two assumptions underlying the use of WMQ:

1.) The number of outliers is less than 25% of all the mre values. This assumption is generally true.
2.) If the estimation of 75% of the projects is acceptable, the model is desirable. Because of the present low level of poor estimation accuracy, this assumption is reasonable.

Unlike the mean measures, the WMQ is not influenced by extreme mre values, and at the same time it provides more general information about the distribution of mre than the single value measures. It will be shown later that the WMQ presents a good average of mre in evaluating accuracy of software cost estimation. The WMQ is consistent with the MRE provided that the estimation is not obviously biased (tending to under/overestimate) and there are no outliers (extreme large values).

3. MEASURES OF CONSISTENCY

A model that is sensitive to the influence of various productivity factors may nonetheless consistently overestimate or underestimate development, if the standard productivity rate assumed by the model is significantly different from that of the environment in which the software was developed. Models developed in different environments do not work very well without calibration. A consistently overestimating or underestimating model is easier to calibrate than an inconsistent one. Therefore, besides accuracy, consistency is another important feature for an estimation model.

3.1 Correlation Coefficient of Estimates and Actual Values (SDR): -

To measure the level of consistency, some researchers have used the correlation coefficient, SDR, between observed and estimated values. This measure tests the linear association between the actual values and estimates. For a highly consistent model, R should be close to 1 ($-1<R<1$), otherwise it is close to 0. If R is negative, it indicates that larger actual values are associated with smaller estimates. R is the square root of R, the coefficient of determination introduced earlier. So SDR is not consistent with the ratio measure which has been illustrated to be more suitable for software cost estimation. Moreover, as R2, SDR is influenced by the variance of data. The greater the variance of actual values, the larger the denominator in the expression. R varies according to not only the estimation accuracy but also the variance of data. We need a consistency measure, which assesses the estimation on the basis of ratio measure and is independent to the distribution of the actual observations.

Suppose that a model was developed in environment A and a set of data, which was collected from software projects developed in environment B, is used to test the estimation consistency of the model. [38] For each estimation there is a ratio –

$$R_i = est_i / act_i \ (i=1,2, 3..., n)$$

In the case of consistent estimation, the values of r (i = 1,2, 3..., n) are close to one another. On the other hand, if the values of r; spread over a wide range, the estimation is not consistent. The closer to one another the values of r_i are, the more consistent the estimation is. Statistically, standard deviation is a measure of variation or spread of the r_i's. So it is proposed to use the standard deviation of r; (SDR) as a measure of estimation consistency,

$$SDR = (\sum((r_i - r)^2)/(n-1)) \wedge (1/2)$$

where r is the mean of r. 's (; =l,2, 3… /i) The smaller the SDR, the more consistent the estimation. It can be shown that standard deviation of relative error is equal to SDR. Because the assessment of estimation accuracy is based on relative error, SDR is related to estimation accuracy. Therefore, SDR can be used to calibrate a model in order to improve the estimation accuracy in different environments.

4. ASSESSMENT OF THE PROPOSED MEASURES AND CRITERION

4.1 Accuracy Assessment

Table 1 uses FP as size measure while Table 2 uses WFP. Table 2 also includes consistency results, which are to be compared with Table 3.

Table 1. Accuracy of FP as size measure

Criterion	Q_3	PRED(0.25)	WMQ	MRE
1	0.66	0.42	0.45	0.67
2	0.70	0.11	0.62	0.58
3	0.56	0.37	0.42	0.58

Table 2. Accuracy and consistency of WFP as size measure

Criterion	Q_3	PRED(0.25)	WMQ	MRE	R	SDR
1	0.43	0.49	0.32	0.33	0.8428	0.439
2	0.45	0.48	0.34	0.30	0.8389	0.344
3	0.44	0.56	0.31	0.32	0.8406	0.423

The first observation is that the compared measures of accuracy, Q3, PRED(0.25), WMQ and MRE, are not consistent in both tables. This observation is not unexpected because the Q^ and PRED(0.25) are stochastic.

The second perception is that Criterion 2 prompts the best MRE and Criterion 1 prompts the most noticeably bad MRE. As examined in the past area, Criterion 1 depends on distinction measure while MRE is a proportion measure.

In this manner, the MRE of Criterion 1 is bigger than that of Criterion 2 and Criterion 3, which depend on relative mistakes. Standard 2 prompts inclination towards underestimation and MRE favours underestimation. Along these lines, Criterion 2 has the best MRE. Paradigm 3 does not have over-or underestimation inclination. Accordingly, the MRE of Criterion 3 is situated between those of Criterion 2 and Criterion 1.

4.2 Consistency Assessment

Table 3. Accuracy and consistency results from reduced data set

Criterion	Q_3	PRED(0.25)	WMQ	MRE	R	SDR
1	0.44	0.49	0.33	0.34	0.7900	0.441
2	0.45	0.49	0.33	0.30	0.7885	0.345
3	0.44	0.56	0.31	0.32	0.7891	0.425

In this area, it will be first demonstrated that SDR is superior to SDR, on the grounds that R is affected by the estimation result as well as the difference of the real exertion, while SDR is not impacted by the later. For this reason, the information of one anticipate, which includes the biggest advancement exertion, is erased from the informational collection. With this change the fluctuation of the genuine exertion changes. Table 3 demonstrates the precision and consistency comes about because of the diminished informational collection.

Looking at Table 2 and Table 3, we find that the Q qualities, WMQ and MRE of every Criterion are practically the same in the two relating circumstances. The consistency ought not be diverse on the grounds that it gauges the nature of a model in a particular domain and it ought to be free of the fluctuation of the real exertion. Nonetheless, the change of fluctuation makes the R values diminish by more than 0.0500. Then again, the SDR values just change by under 0.002, which is relatively little. In this manner, the SDR is better over R in the perspective that the previous is not affected by the change in exertion.

5. ESTIMATION METHODS

All the cost estimation strategies are based upon some type of similarity: Historical Analogy, Expert Judgment, Models, and so on., the part these techniques play in creating a gauge relies on where one is in the general life-cycle.

5.1 Historical Analogy

The means utilizing evaluating by relationship are - describing the proposed extend; Selecting the most comparative finished tasks whose qualities have been put away in the chronicled database', deriving the estimate for the proposed project from the most similar completed projects by analogy.

The main advantages of this strategy are, the estimation depend on real venture trademark information. The estimator's past involvement and information can be utilized which is difficult to be evaluated. The contrasts between the finished and the proposed venture can be distinguished and impacts evaluated.

5.2 Expert judgement

The strategy depends vigorously on the experience of their insight in comparative improvement situations and generally kept up databases on finished tasks and the exactness of the past ventures.

The advantages of this strategy are –

The specialists can figure contrasts between past venture understanding and necessities of the proposed extend; The specialists can consider extend impacts brought on by new innovations, models, applications and dialects required later on venture and can likewise calculate remarkable work force attributes and communications, and so forth.

The disadvantages incorporate –

This strategy can't be measured. It is difficult to archive the components utilized by the specialists or specialists bunch. Master might be some one-sided, idealistic, and cynical, despite the fact that they have been diminished by the gathering accord. The master judgment technique dependably compliments the other cost evaluating strategies, for example, algorithmic strategy.

5.3 Delphi Approach

This strategy endeavours to accumulate the feelings of a gathering of specialists with the point of delivering an exact fair-minded gauge. [22] It is an organized system of master judgment and is basically a shape based strategy including a multistep technique: Experts are issued the detail and estimation frame by the organizer.

Advantages of the Delphi Estimation Process:

a.) Free of social weight, identity impact, and individual predominance

b.) Allows sharing of data and thinking among members.

c.) Conducive to free thinking and slow detailing.

d.) Respondent board gives expansive logical point of view on issues and issues.

e.) Can be utilized to achieve accord among gatherings threatening towards each other.

Disadvantages of the Delphi Estimation Process:

a.) Judgments are those of some chosen assemble, and may not speak to winning sentiment.

b.) Tendency to take out extraordinary positions and constrain widely appealing agreement.

c.) More tedious than ostensible gathering process.

d.) Requires expertise in composed correspondence.

e.) Requires satisfactory time and member responsibility (may oblige 30 to 45 days to finish whole process).

5.4 Algorithmic Method

The algorithmic strategy is intended to give some scientific conditions to perform programming estimation. These numerical conditions depend on research and chronicled information and utilize data sources, for example, Source Lines of Code (SLOC), number of capacities to perform, and other cost drivers, for example, dialect, outline philosophy, ability levels, hazard appraisals, and so on.

Advantages –

It can produce repeatable estimations.

It is anything but difficult to adjust input information, refine and tweak equations.

It is effective and ready to bolster a group of estimations or an affectability examination.

It is impartially adjusted to past involvement.

Disadvantages –

It can't manage extraordinary conditions, for example, excellent staff in any product cost evaluating works out, outstanding cooperation, and a remarkable match between ability levels and errands.

Poor measuring inputs and mistaken cost driver rating will bring about off base estimation.

Some experience and elements can't be effortlessly measured.

5.5 Bottom-up approach

Every part of the product framework is independently assessed and the outcomes totalled to create a gauge for the general framework. [22] The necessity for this approach is that an underlying plan must be set up that demonstrates how the framework is disintegrated into various segments.

Advantages –

It allows the product gathering to deal with a gauge in a practically customary manner and to deal with gauge parts for which the gathering has a vibe.

It is steadier on the grounds that the estimation mistakes in the different parts have an opportunity to offset each other.

Disadvantages -

It might disregard a hefty portion of the framework level costs (coordination, design administration, quality confirmation, and so forth.) related with programming improvement.

It might be off base on the grounds that the important data may not accessible in the early stage.

6. MEASURING RELATIVE ACCURACY

Let the proportion of the anticipated an incentive to the genuine incentive as a measure of exactness. We might mean this by Q, for remainder. Take note of that Q is the supplement of the relative mistake: 1─ (relative blunder), thus separated from the move of one unit, will have an indistinguishable appropriation from the relative mistake. The supplement of the relative mistake does not appear to have a built-up name, so Q could be alluded to as the 'relative precision' or 'exactness proportion', with 1.0 being the perfect esteem. Kitchenham et al. (2001) watched that Q was lopsided in light of the fact that its esteem is limited from underneath by zero, while it is unbounded from above. "Since the variable Q is characterized on the range 0 to ∞ with a hypothetical mean of 1, Q must, by definition, be skewed". [20] We can beat this asymmetry issue by should just take the logarithm. It can then be utilized as a fitting paradigm by applying minimum squares to Ln Q to deliver relapse models. It can likewise be utilized for contrasting the relative precision of contending techniques by looking at the entirety of squares of Ln Q.

The plot of the residuals from Ln(Q) relapse demonstrated that about portion of the mistakes were certain and the other half negative. Despite the fact that a fantastic outcome, it doesn't seem to have been powerful therefore, perhaps because of absence of hypothetical support. We expect to fill this crevice by giving some hypothetical investigation beneath.

Ten measures were included:

(f-g)/f , (f-g)/g , (f-g) /[½(f+g)] , Ln (g/f)

(f-g)/(fg)1/2, (f-g)/ min(f,g) , (f-g)/max(f,g)

We instantly observe that these relate to a few measures of expectation precision as proposed for use in anticipating. The first of these measures is the relative mistake, the second is MER - the blunder in respect to the anticipated esteem - it has the inverse issue to MRE in that it tends to over-foresee when utilized for fitting (Lokan, 2005). The third compares to SMAPE. The last two measures have showed up in the cost estimation writing under the names of adjusted relative blunder, (Miyazaki et al. 1991), and reversed adjusted relative mistake

(Miyazaki et al. 1994). The previous thinks about the mistake in respect to the genuine incentive on account of over-estimation, and in respect to the anticipated an incentive for under-estimation. The transformed adjusted relative mistake does the switch of this. The accompanying properties were considered for choice of an appropriate pointer - symmetry, additivity, coherence, and homogeneity. Accordingly, the last pointer as most reasonable that was left was - ln(g/f).

This measure is symmetric as in trading f and g only modifies the sign:

ln(predicted/genuine) = ln(predicted) – ln(actual)

= – [ln(actual) – ln(predicted)] = –ln(actual/anticipated)

It likewise gives inside a similar metric both a proportion and a distinction.

We additionally explored different avenues regarding the measure of clamor in the information by changing the standard deviation of the blunder. The outcomes are shown in Table 4.

Table 4. Performance of different accuracy measures in identifying the true underlying power function model which generated the data, at different noise levels

Noise level	Percent correct using MAPE	Percent correct using Σ (ln Q)^2
0.1	86%	88%
0.2	43%	59%
0.3	19%	43%
0.4	7%	34%

As expected, when the clamor in the information is little the execution is great. Be that as it may, as the clamor level builds MAPE is obviously observed to be the more terrible entertainer.

Henceforth the log precision proportion is superior to MAPE particularly at higher clamor levels.

7. CONCLUSION

The distinction measures of precision support the estimation for little activities. Consequently, it is contended in this paper measures of exactness ought to be founded on relative blunder of estimation. As the MRE (the most broadly utilized measure of precision) is impacted by anomalies and favours underestimation, and single esteem measures are stochastic, the WMQ is proposed for exactness assessment. The WMQ incorporates more data on the estimation than single esteem measures, so it is less stochastic. It is likewise steady with MRE when there are no anomalies and estimation is impartial. Consistency inspects the model's level of simplicity of alignment. A reliably overestimating or thinking little of model is more effectively aligned than a conflicting one. The connection coefficient R amongst watched and real values has been utilized to assess consistency. The R supports an informational index with substantial difference. It is resolved by estimation as well as by the dissemination of the genuine

values. In this paper, the standard deviation of the proportions of the gauge to genuine exertion (SDR) is proposed as a measure of consistency. The SDR is a measure of the variety or spread of the relative blunder.

The vital lesson to take from this paper is that nobody technique or model ought to be favoured over all others. The look for solid, exact and ease estimation strategies must proceed. Likewise, more reviews are expected to enhance the precision of cost gauge for upkeep ventures. The conclusion is that no single method is best for all circumstances, and that a cautious correlation of the aftereffects of a few methodologies is well on the way to deliver practical appraisals.

This paper likewise clarified why MAPE relapse prompts expectations that are too low and considered an option in light of the log of the exactness proportion, Ln(Q). It has been demonstrated that Ln(Q) is the main shape known to fulfil the arrangement of alluring properties which they indicated.

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