

# Conceptual estimating tool for technology-driven projects: exploring parametric estimating technique

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## Abstract

This paper examines a parametric estimating technique applied to technology-driven projects. Parametric cost estimating is a widely used approach for bidding on a contract, input into a cost benefit analysis, or as the pre-planning tool for project implementation. Extensive literature reviews suggest that effective parametric estimating methodology is becoming an essential tool for technology-driven organizations. The use of parametric estimating in budgeting, scheduling, and control of projects will enhance the ability of project management organizations to effectively and efficiently utilize valuable resources. The benefit of parametric estimating is its use as an estimating model for better determining potential resource requirements during the project pre-planning and conceptual phase.

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*Keywords:* Parametric estimating; Technology-driven project; Project management; Comparative analysis

## 1. Introduction

The enhanced and competitive business environment and the integration of technology into various aspects of everyday life have changed the landscape of project management. Project-driven organizations must utilize available information better along with innovative tools and techniques to adapt to this new setting. The organizations that increase their expertise and leverage certain skills will reap the associated benefits.

This paper examines parametric project cost estimating practices by investigating how parametric estimating techniques impact a technology-driven project. Parametric estimating uses a subset of independent variables to predict the cost of a project. These independent variables may be specifications, features, function, or some other high level descriptive elements that is used to define the scope of the deliverables at an early stage when there is a lack of detailed information. Extensive literature reviews were conducted to capture and assess the current trends and applications of parametric estimating. The industries investigated include

electronics, construction, textile, manufacturing, aerospace, and transportation sectors.

## 2. Principle of parametric estimating technique

Parametric estimating technique does play a very significant role in the early stage of project lifecycle regardless of the assertions that the results may lack the precision of a detailed estimate. Fig. 1 depicts a suggested timeline for parametric estimating.

A parametric estimation is obtained by using Cost Estimating Relationships (CER) among the project characteristics and applying an algorithm to determine an approximation of the total project cost. The characteristics may be physical attributes, performance specifications, or functions. It is a methodology associated with an organization's strategic approach to project management. CERs are proven based on cost-to-cost or cost-to-noncost variables. For example, with cost-to-cost relationship, the cost of the independent variable may be used to predict the cost of the dependent variable such as using the cost of labor hours of one component to predict the cost of labor hours of another component. In a cost-to-noncost scenario, the number of output items may be used to predict the cost of labor hours. The relationships

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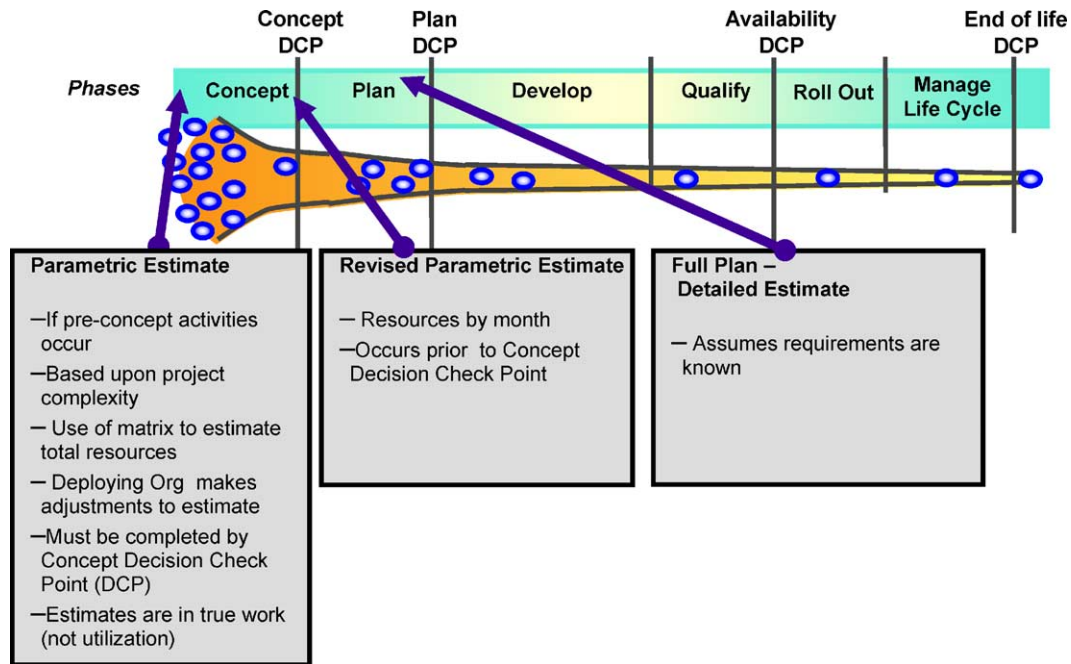


Fig. 1. Suggested timeline for parametric estimating.

can range from a simple one-to-one relationship to a complex algorithm. A combination of complex relationships is referred to as an estimating model.

A parametric estimate requires far less information concerning labor and material than that of a detailed estimate. Hamaker (1995) argues that most CER's are linear in nature suggesting that there is a single value of the independent variable associated with a particular cost. It is possible for a CER's to have inflection points but does not occur often. It is also typical for the model to estimate the first unit cost. Any change in costs associated with a learning curve is calculated separately.

### 3. Evolution of parametric estimating technique

The origins of parametric estimating originated during World War II to predict the cost of the manufacturing of aircraft. It was based upon a work by T.P Wright involving learning curves and mathematically determining the decrease in unit costs as the manufacturing process is repeated (DOD, 2000). During the 1950's, the Rand Corporation expanded the use of parametric estimating, also for the airplane industry, and made the term Cost Estimating Relationship (DOD, 1999). The methodology was used for estimating the cost of military programs for the Department of Defense in United States. An example of CER's used to determine the cost of an airplane acquisition is the use of features such as speed, range, and altitude of the aircraft. In 1975, the RCA Company released a commercial hardware estimating model (DOD, 1999). It was used to predict the cost of systems based on various

factors such as weight and size, packaging, and schedule. In 1994, the Joint Government/Industry Parametric Estimating Initiative steering Committee was formed to determine ways to increase the use of parametric estimating methods. The most significant result of the committee was the development of the Parametric Cost Estimating Handbook (DOD, 1999).

### 4. Various parametric estimating tools and techniques

As technology evolves, new tools will be developed for improving the accuracy of estimating technology-driven projects. The Parametric Estimating Handbook states that the type of software development methodology has an impact on the total project costs. The estimating tools should take the type of methodology into account. These include the waterfall methodology, evolutionary development, incremental development, prototyping, spiral development, and object-oriented development.

Each methodology has unique characteristics. The waterfall methodology is the traditional method of focusing on the complete documentation of requirements prior to coding. The evolutionary development method involves coding iterations of the final product that are refined along the process. Incremental development provides for the production of a product that gradually contains increasing functionality. Prototyping uses an experimental system to determine requirements. Spiral development introduces risk analysis at the beginning of each phase and object-oriented development focuses on reuse.

Burgan (2002) identified advancements based upon technology that help in parametric estimating. These are enhancements and innovations in tools such as:

- Databases of cost information
- Spreadsheet and statistical applications
- Internet access to expert data (internal and external)
- Collaboration methodologies and tools

Roy et al. (2000) assessed two different methodologies and tools. The first one was a computer model that can be used for risk analysis of cost estimating called Stochastic Aggregation Model (SAM). It is a monte carlo simulation program designed to help the cost analyst quantify the uncertainty associated with a parametric cost estimate. A second tool, named PREDICT, is used to perform risk identification. In the case study documented in the article, it was combined with Monte Carlo simulation to perform a risk analysis.

Arioli and Masi (2002) provided a description of Eastman Kodak's EST1 Estimating System. It is a parametric model originally built in the 1990s and improved over time. The tool is used primarily for estimating the cost of the construction of building additions. Wang (2002) developed SIM-UTILITY, a model based on a utility theory and facilitated by a cost simulation approach. He states that utility theory is applied to include the owner's preference relative to upper and lower boundaries for characteristics used to determine the cost, while the simulation approach is used to provide the probabilities of certain project cost data to support execution of the utility theory. His case was the determination of project ceiling prices for construction projects.

## 5. Applications of parametric estimating technique

The risk of cost growth is increased for long duration projects. Some of the factors that influence the cost growth are the introduction of new technologies, changes in the scope of the project, changes in specifications or function of the deliverable, fluctuations in the marketplace, changes in the political climate and changes in the project schedule. The longer the duration of the project the greater the probability of one of these elements having an effect on costs.

Parametric cost estimating is particularly suited to the earliest stage of design to cost approach; however, it can be used at any stage of a project as a basis of comparison or validation of other estimating methods. An example stated in the literature was a case involving the consideration of risks (Roy et al., 2000). It focused on using Cost Estimating Relationships to predict the probability that the independent variable will change values.

### 5.1. *Airplane, weapons acquisition, and space exploration*

Parametric estimating was first developed to meet the needs of estimating new technology projects for the government such as the airplane, weapons acquisition, and space exploration program. It was widely used in industries with long project durations and high capital investment costs as a way to ensure an adequate return on investment. The initial focus of the use of parametric estimating was on estimating 'lifecycle' costs. Traditionally, the widest known use of parametric estimating is in the construction industry where it is used to reduce the time and subsequent expense to bid a project. More recently, applications have expanded to ensure a quality of delivered design at planning stage by using historical data to estimate the cost of design phase. For example, Camargo et al. (2003) addressed the development of CERs by applying parametric estimating to the textile industry.

### 5.2. *Engineering and construction*

Estimating the cost of developing intellectual property such as engineering design is significantly different than estimating the cost of physical property in construction, however this is becoming increasingly more prevalent. Burgan (2002) observed that as many as 75% of companies in the construction industry believe that automation presents an opportunity to improve productivity. The interest in increasing the productivity of existing workers is heightened by the desire to avoid the increased costs associated with hiring additional resources. The basis of this automation is to capture the intellectual property of experienced workers and disseminate it to lesser skilled individuals.

The cross discipline nature of projects is leading to complexity in parametric estimating. An example is the infusion of technology in traditionally static processes such as infrastructure projects. The construction of a transportation system or a water and sewer system was fairly easy to estimate accurately based upon the wealth of knowledge and experience available in implementing these projects. However, that has now been complicated by the dynamic nature of the monitoring technologies being installed as a component of these projects. Many of the existing estimators do not have the combined experience of estimating technology components along with the traditional infrastructure components. Therefore, the technology impacts of a project are increasingly becoming a significant part of the final estimate.

### 5.3. *Manufacturing*

Another area of application is manufacturing conversion costs for new technologies in the electronic industry, a very competitive environment due to globalization, high demand, and speed in technology changes. New technology

may also be driven by legislation. An example found in a doctoral dissertation proposal was to estimate the requirement to remove lead from electronic equipment (Gu, 2003). Since lead was a component of many of the items contained in electronics, new approaches had to be developed which eliminated the lead based processes. This introduction of new technology contributed to an increase in costs but had no historical data from which to draw for estimating. A valid approach is that of using a technique to predict the maximum result of the cost estimate and its probability. This would provide a range of costs, helpful when assessing a new concept.

## 6. Discussing limitations of parametric estimating technique

### 6.1. Accuracy

Oberlender and Trost (2001) identified four determinants of estimate accuracy:

- Who was involved in preparing the estimate
- How the estimate was prepared
- What was known about the project
- Other factors considered while preparing the estimate

He also describes the accuracy of parametric cost estimates as being affected by:

- Changes in project scope
- Changes in design standards
- Incorrect unit cost/quantity assumptions
- Unforeseen problems in implementation

Harbuck (2002) stated that an estimate derived with final design information has an expected accuracy range of approximately  $+10/-5\%$ , while a parametric cost estimate made from information with the project definition from 1 to 15% complete has an expected accuracy of  $+30/-25\%$ . Arioli and Masi (2002) argued that one can expect estimation accuracy in the range of  $+50/-30\%$  before contingency using a specific tool which he observed in the area of construction. These are relatively broad ranges for estimate accuracy which apparently is acceptable given the stage of the project and the use of the estimates.

The overall purpose for an accurate cost estimate is its use in establishing the budget for a project and as a tool used for scheduling and cost control. When bidding on a project, the accuracy of a cost estimate has a number of different implications. The most obvious is the effect on winning the contract. An estimate that is too high may place one out of the running for the award of the contract. An estimate that is noticeably too low may give the impression that one does not understand the requirements of the contract and therefore lead to a failure to obtain it. An even worst case

scenario is for a cost estimate to be too low but still results in a contract award. In this scenario, it may be improbable that the project can be completed or cannot be completed in a profitable state. A significant implication of parametric estimating on the bidding process is simply decreasing the amount of time consumed in the development of an estimate. One aspect of timeliness involves being able to respond to requests for proposals. The other aspect is the assumption that the preparation of a parametric estimate which consumes less time is also less costly to prepare.

Normally when a parametric cost estimate is used within a portfolio management process, the portfolio consists of internal projects. The profitability impact may not be as directly observable as with an external project, however it is still a factor. The profitability factor may not be reflected as expenses versus income. It is reflected in the utilization of resources and the return from the use of those resources. If the lack of accuracy of a parametric estimate causes one to choose the 'wrong' set of projects for a portfolio, the results will be a lost opportunity to utilize the resources most effectively. This depends upon the criteria used for project selection. If cost/benefit is a heavily weighted criterion, an inaccurate estimate may result in one project mistakenly showing a greater return on investment thus possibly contributing to an incorrect decision.

How an inaccurate parametric cost estimate affects the building of an initial project plan depends upon the reason for the inaccuracy. The greatest impact of course would be related to the situation where the estimate is inaccurate due to missing requirements. Any plan built using these elements as input would be incomplete. The opposite is true if the inaccuracy is the result of including too much into the scope that was used as input to the creation of the parametric cost estimate. The project would not be incomplete but it would contain elements not necessary to deliver the project. If the cost estimate is inaccurate solely as the result of incorrect pricing, it may not have as much of an impact on a project plan unless there is a relationship between the incorrect pricing and availability of the material or resource.

Construction Industry Institute created a team to focus on improving the estimating process (Oberlender and Trost, 2001). The Improving Early Estimates Research Team developed a scoring procedure for measuring cost estimate thoroughness, quality and accuracy. The procedure resulted in the ability to assess an estimate based upon criterion that they determined was important. This criterion included identification of who performed the estimate, how the estimate was prepared, what was known about the project, and a category of other criteria. There were reported cost savings of up to 80% in the areas of proposal preparation, evaluation, and negotiation. There were also reduced cycle times of up to 80%. It is asserted that the accuracy of an estimate is greatly affected by the experience and skill of the person(s) performing the estimate. This is tempered by the involvement of the project manager, the review

and acceptance process, as well as the purpose of the estimate. The team also identified important factors and grouped them into an ‘other’ category. These included items such as project type, contract type, government regulations, labor productivity, financial considerations (tax and cost of money), and other significant items that should be considered in preparing the estimate.

For a technology-driven project often the greatest challenge in the creation of an accurate prediction is estimating the cost of software development. It depends upon the scope of work as well as the productivity of the software engineers. The scope of work may be measured by using function points as a cost estimating relationship element. Function points are based up determining the number items in a category of characteristics of a project such as external interface, user inquiries, user outputs, user inputs, internal files. The number of lines of code and subsequently labor hours are derived from the results and used to predict the total cost. Unfortunately, there is no commonly agreed upon standard for counting function points. It may be highly influenced by the experience of the estimator and therefore is subject to inconsistent or inaccurate estimates results.

### 6.2. Data availability

The reason for the estimate may drive the method utilized; however, the method is also often driven by the availability of data. Since parametric estimating is done early in the life of a project, detailed information about design is normally not available. For transportation projects, Harbuck (2002) surmised that the available information is in the range of 5–20%. Although not explicitly stated, the literature gives the impression that this upper range is high for technology related projects. Even in situations where significant data is available, Staub-French et al. (2003) speculates that the quantity-based CER’s are not completely adequate because the estimator’s rationale for the relationship is not captured.

In the absence of complete information, steps can be taken to improve the parametric estimating process with technological aids and thereby increase the accuracy of the estimates. Technologies that improve estimating methods focus on:

- Capture and retention of historical information
- Ease of manipulation of a cost database
- Application of algorithms
- Statistical validation
- Execution and reporting

### 6.3. Comparing different approaches

Parametric cost estimating is performed using a variety of methods. Bajaj et al. (2002) suggests it requires an effective cost accounting system, an accurate historical

accounting database, normalization of the data, exclusion of outliers, and the development of sufficient cost estimating relationships.

A cost estimating relationship is a proven relationship between a certain characteristic and an estimated cost. This relationship is something that has developed over time and is based upon historical data. The algorithm used to define the cost estimating relationship may be elementary such as a one to one relationship or it may be extremely complex.

The particulars of an industry or project determine what factors can be used to establish meaningful cost estimating relationships. For example, in the deployment of software applications, the following factors can have a predictable impact upon the deployment costs (Watson, 2001). These factors may in fact become a component of a Cost Estimating Relationship if an algorithm can be applied to convert the value of the independent variable listed below into a portion of costs for the project.

- Number of users supported
- Number of organizations deployed
- Number of similar users within an organization
- Number of simultaneous organizations deployed
- New deployment versus an upgrade of an existing system
- Number of new interfaces
- Number of process changes required
- Duration of the project
- Type of system architecture
- Overall project complexity

The Parametric Estimating Handbook is a tremendous reference for methodology. It is very clear and thoroughly describes various approaches for the creation, validation, use, and maintenance of a parametric estimating process. A review of additional literature also yielded a number of different approaches for the development of a parametric cost estimate. A common element was a primary focus on validation of the Cost Estimating Relationship.

In a unique methodology as compared to the rest of the literature reviewed in this paper, Roy et al. (2000) examined combined parametric costing and risk analysis approaches to perform a cost risk analysis. They describe two risk assessment methodologies that can be used with a parametric cost estimate. Particularly, the risk analysis methods looked at how the independent variables changed as the product matured through the design process and thus affecting the accuracy of the cost estimate. The paper followed the traditional risk management process which includes risk identification, assessment, analysis, and mitigation.

Table 1 compares various steps which different literature have identified for creating and validating CERs. Table 2 summarizes three various approaches of applying CERs and obtaining consistency in estimates.

Table 1  
Steps for identifying cost estimating relationships

Koenigseker (1982)	Gu (2003)
What are we building	Cost drivers selection
Where are we building it	Data Collection
When are we building it	Regression-fit CER
How are we building it	Test CER
How big are we building it	Select best CER
Who is building it	
What is it intended to do	

Table 2  
Approaches for obtaining consistency in parametric estimating

Black (1984)	Bajaj et al. (2002)	Koenigseker (1982)
Definition of the problem	Effective cost accounting	Develop standards
Collection of the data	Historical database	Develop parametric sets
Normalization of the data	Normalize data-multipliers	Define the project
Interdependencies	Exclude outliers	Apply sets to standards
Derivation of the CER	Statistical analysis—CERs	
Establishment of limitations	Apply multipliers	
Documentation	Prepare a template	

**7. Benefits of implementing parametric estimating technique**

The majority of the literature reflected similar benefits associated with parametric estimating. The primary benefit is the ability to provide a timely estimate based upon limited knowledge of the project as long as sufficient information is available. This facilitates quicker response to competitive business environments. This is possible because the Cost Estimating Relationships are based upon actual historical data from related projects which reflects the impacts of cost growth, schedule changes and design changes. Statistical techniques are used to validate and maintain the relationships. The result of going through an estimation process provides greater insight and understanding of the major cost drivers of a particular project.

Given an adequate methodology, the resulting estimates are less subjective and less prone to random variation and error. The use of tools to support the methodology facilitates the capture and analysis of actual data as it occurs. This ensures refinement of the estimation capabilities as long as future projects bear resemblance to past projects. In total, it results in a defensible estimate created within a reasonable cost. This is an important element in funding and budgeting decisions because few organizations can survive in the competitive business environment without effectively managing business-related information.

**8. Conclusion**

Competitive advantage is based upon the exploitation of the core competencies of an organization and its ability to optimize the effective and efficient use of its resources. The introduction and increased investment in technology must be a part of an overall strategic plan to ensure that it makes a sustained contribution to the competitive advantage of an organization. As increasingly more projects are integrated by technology components, the ability to estimate total costs and plan the efficient use of resources becomes more complex.

From the review, we conclude that parametric estimating techniques are a way to facilitate effective estimates given limited but sufficient information. The extensive literature reviews suggest that parametric estimating can be applied to technology-driven projects effectively and it is an essential tool for organizations to remain competitive. Specific characteristics of a technology-intensive project can be used to form cost estimating relationships providing the ability to predict project costs with limited data. However, the accuracy of the estimates will depend upon the validity of the cost estimating relationships and the effective use of historical data.

Overall, various literature suggest that organizations are finding great benefit in the investment in parametric estimation methodologies and tools. Much of the literature focused on the development and validation of Cost Estimating Relationships. There is a consensus on its importance however, there is still quite a bit of on-going research remaining to be done in this area as the introduction of new technology changes the characteristics of projects.

To summarize, the past few years has yielded greater understanding and use of parametric estimation methodologies and tools. This is leading to the ability to simplify the complexities of technology-driven projects so that the major cost drivers can be identified, validated and maintained. The use of these estimates in budgeting, scheduling and control of projects will enhance the ability of project management organizations to effectively and efficiently utilize value resources. While there are discrepancies among the literature as to specific methodology, specific approaches must be followed to insure accurate estimates and to exploit information that is now available via current technologies. Finally, there is virtually no evidence in the literature supporting a lack of value to parametric estimating for projects in a technology-driven environment.

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