Productive System Engineering Cost Estimation Model

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ABSTRACT
Development of quality software is the prime need of the development world. Proper planning and requirement analysis are the contributory factors for the successful development of a system or software. The cost being an important factor to be considered for any such development requires a deep insight for its estimation in advance. With the increased requirement of complex systems, the need of a quality software meeting the cost, schedule, and performance targets as per the estimations and plans is also needed. Systems engineering concepts, tools and technologies play a vital role in achieving the targets associated with any development project. Thus, to ensure the achievement of goals in an effective manner, the Systems Engineering (SE) tools and technologies are to be revived to match its pace with the requirements. A brief introduction of System Engineering and its relevant concepts has been presented in this paper. The Productive System Engineering Model has been introduced with its implementation and performance evaluation. The paper described the implementation of the proposed model in a real world.

Keywords
Systems Engineering, Size Drivers, Cost Drivers, Cost Estimation, Cost Estimation Relationship

1. INTRODUCTION
Systems Engineering (SE) is concerned with the creation and execution of an interdisciplinary process to confirm that the customer and the relevant stakeholder requirements are satisfied in a high quality, trustworthy, cost efficient and schedule acquiescent method throughout a system's complete life cycle. Systems engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, with the documentation and system design and validation, while considering the complete problem's operations, cost & schedule, performance, training & support, test and manufacturing[1][4][6][9]. SE integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation. Thus, the productivity of the individual as well as the team is analyzed to be one of the contributory cost driver to be added with the already recognized drivers.

Systems engineering considers business and technical requirements of all customers with the am objective of providing a quality product that encounters the user needs. The different cost estimation's factors, like effort, staff requirements and schedule are the important information contributors for project's key activities relevant to proposal formation and execution and provides inputs for project order, proposal, budget, staff allocation, project planning, progress monitoring, control, etc [5][6][8][9]. Irrational and unreliable estimates are the foremost cause of project failure, which is proved by many IT relevant professionals and surveyors [2][3]. Thus effort estimation and hence cost estimation of any candidate system before its development is a prime requirement of the entire development procedure.

Here, this paper describes the concept, design and implementation of cost estimation model prototype titled as Productive System Engineering Cost Estimation Model (PSECOMO). In this paper a system engineering cost estimation model has been presented with its application on sample data. The Introduction of Productive System Engineering Cost Estimation Model (PSECOMO) and the information required to support cost estimation has been presented in section II of this paper. The basic information about the system engineering cost parameters has been depicted in section III of the paper. Section IV depicts the effort estimation and hence cost estimation through PSECOMO. Section V concludes the discussion. .

2. PRODUCTIVE SYSTEM ENGINEERING COST ESTIMATION MODEL
It is clear that our everyday lifestyle is driven by the technologies and technology enabled systems. Most of our everyday functionality is reliant on large scale man made systems that offer useful technological capabilities. The arrival of these systems has created the need for systems thinking and thus gives a way towards systems engineering. Productive System Engineering Cost Estimation Model (PSECOMO) is a methodical, disciplined approach for the cost estimation of design, realization, technical management, operations, and retirement of a system. It is an interdisciplinary systems engineering oriented model that focuses on how to estimate cost for design and manage complex engineering systems over their life cycles.

Data and its analysis is the key contributor of the PSECOMO. Thus, analytical study of data of various system engineering projects or system development is required for the model. But, for the purpose of base modeling, a single project has been considered, that could be calibrated and reformed with the help of other project's information. For initiation of the PSECOMO working, project from a cloud computing service Provider Company has been considered for case study. The project involves the provision of advanced methods for data storage and data retrieval at to or from remote servers. Thus the project intention was to develop a distributed application for bulky data storage and retrieval will be key to the success of PSECOMO because it will enable reasonable estimates of Systems Engineering effort. This data is critical in understanding the capabilities of the local organization. The organizational database and other project's information can be used in creating a local calibration of the model [8]. The success of PSECOMO largely depends on the quality and quantity of data received to calibrate it.

A data collection form is being developed to facilitate this process and ensure consistent interpretation of the size and cost drivers. Once the data is collected and validated, it will be used in determining the relative significance of the parameters and general form of the model.

The stated PSECOMO modeling is expected to meet the needs and applicable to multiple fields, with the sustained participation of the Systems Engineering civic and the corporate associates.

3. COST PARAMETERS AND PSECOMO ESTIMATES

The project source code, some project details and Delphi survey will help in making a cost estimate. Since, a source code can't be obtained before starting the project, but the approach like "post-mortem analysis", is to be followed for the estimation. The company has already provided the document describing the project concept. The identification of the size and cost drivers were obtained through Delphi Survey and postmortem kind of analysis in past with the help of a large variety of projects. Also, the values associated with the size drivers and cost drivers were set after identification and analysis of the actual estimates explored from the previous work, available documents or literature by the researchers.

Delphi Rounds

A Delphi exercise was conducted to reach group consensus and validate initial findings. The Wideband Delphi technique has been identified as being a powerful tool for achieving group consensus on decisions involving unquantifiable criteria. It was used it to circulate the initial findings and reach consensus on the parametric ratings provided by experts.Each parameter is part of the Cost Estimating Relationship (CER) that was defined by systems engineering experts [5][8][9].

PSECOMO Cost Drivers: Requirements Understanding (REQ), Architecture Understanding (ARCH), Level of Service Requirements (LSVC), Migration Complexity (MIGR), Technology Risk (TRSK), Documentation (DOCU), Number and Diversity of Installation / Platforms (INTF), Number of Recursive Levels in Designs (RECU), Stake Holder Team Cohesion (TEAM), Personal / Team Capability (PCAP), Personnel Experience/Continuity (PEXP), Process Capability (PROC), Multisite Coordination (SITE), Tool Support (TOOL), Productivity by Individual (PROI), Productivity by Team (PROT) [5][8][9].

PSECOMO Cost Driver's Categories:

Understanding: RQMT, ARCH

Personnel: TEAM, PCAP, PEXP, PROC

Operations: INST, MIGR

Complexity: TRSK, LSCV, RECU, DOCU

Environment: SITE, TOOL

Productivity: PROI, PROT

The specific tools used for making PSECOMO estimates used is SystemStar 2.0. SystemStar has a convenient interface for general users. In SystemStar, generally, a main component and different subcomponents corresponding to separate tasks of a project are created. Few parameters that are not easy to determine are set to their nominal value equal to 1. As per the information provided by the relevant stakeholders and existing literature, the sample project is characterized by Size and Cost Drivers values as calculated below:

3.1 Size Driver's Calculation

Four size drivers viz. REQ (No. of Requirements), INTF (No. of Interfaces), ALG (No. of Algorithms), SCN (No. of Operational Scenarios) are to be determined.

This result has been obtained after using the below mentioned values for the project:

Table 1. Equivalent Values of Size Drivers for the Sample Project

Driver Name	Data Item	Count	Equivalent Values
REQ (No. of System Requirements)	Counted from the System Specifications	20	31
INTF (No. of Major Interfaces)	Counted from interface control documents	20	75.5
ALG (No. of Critical Algorithms)	Counted from the system spec or mode description docs	20	142
SCN No. of Operational Scenarios	Counted from the test cases or use cases	200	4658

3.2 Size Driver's Calculation

Table 2. Values of Cost Drivers for Sample Project

PSECOMO SE Cost Drivers	Req. Level	Value
Requirements Understanding (RQMT)	High	**0.81**
Architecture Understanding (ARCH)	High	**0.84**
Level of Service Requirements (LSVC)	High	**1.36**
Migration Complexity (MIGR)	Nominal	**1.00**
Technology Risk (TRSK)	High	**1.32**
Documentation (DOCU)	Low	**0.88**
Number and Diversity of Installation / Platforms (INST)	Nominal	**1.00**
Number of Recursive Levels in Designs (RECU)	Nominal	**1.00**
Stake Holder Team Cohesion (TEAM)	Low	**1.20**
Personal / Team Capability (PCAP)	Very High	**0.68**
Personnel Experience/Continuity (PEXP)	High	**0.82**
Process Capability (PROC)	High	**0.91**
Multisite Coordination (SITE)	Nominal	**1.00**
Tool Support (TOOL)	Nominal	**1.00**

Productivity by Individual (PROI)	Nominal	**1.00**
Productivity by Team (PROT)	High	**0.81**

The above mentioned values are input to SystemStar as depicted in figure 1 and figure 2.

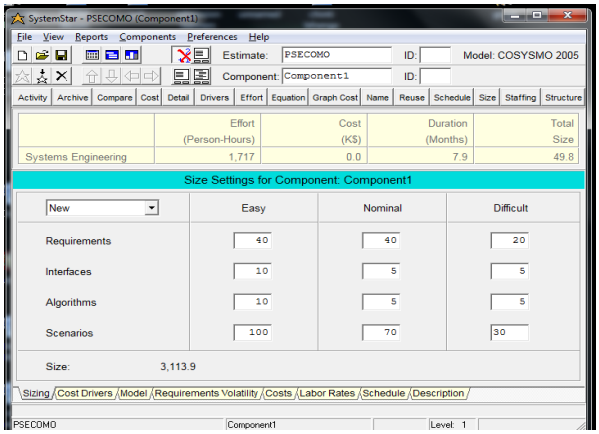

Fig.1 Input - Size Driver's Values

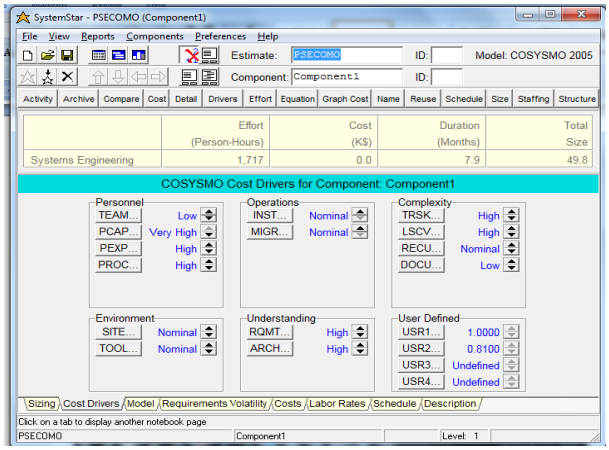

Fig. 2 Input - Cost Driver's Values

The new driver's recognized for this project are PROI (Productivity by Individual) and PROT (Productivity by Team). These new drivers can be added through SystemStar's User Defined Cost Drivers Section as shown in figure 3.

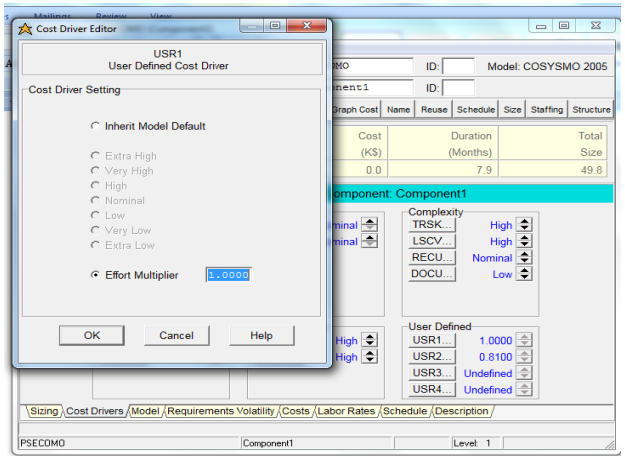

Fig. 3 Input - New Cost Driver's Values

4. EFFORT ESTIMATION USING PSECOMO

Please

The Effort estimation for the stated project is done on the basis of equation 1.1.

Equation 1.1…….

$$PM\ NS = A.(Size)^{E} . \prod_{i=1}^{n} EMi$$

Where, the values used for different constants and variables are:

E = 1.01

Calibration Constant, A=0.1505 (for person months)

Size=(31+75.5+142+4658)$^{1.01}$=(4906.5)$^{1.01}$ = 5341.7

EM_{16} = 0.81*0.84*1.36*1.00*1.32*0.88*1.00*1.00*1.20*0.68*0.82* 0.91*1.00*1.00*1.0 *0.81= **0.5301**

PM_{NS} = 0.1505*(5341.7)*(0.5301) = 426.1929216185129

Therefore, After Round Up, PM_{NS} **= 426.19**

And, **Duration =3.67*(426.19) $^{0.3179}$ =25.15 months**

(Duration =3.67(PM) to the power0.3179)

Whereas,

In case, when the productivity parameters are not included, then in that case EM_{14}= 0.654

And, after Round Up PM_{NS} **= 525.76**

Thus, **3.67*(525.76) $^{0.3179}$ = 26.89 months**

5. RESULTS AND DISCUSSIONS

5.1 Performance Evaluation

For the stated project the actual time to complete the project is **21.5 Months.**

Thus, the performance of the PSECOMO model can be seen by calculating the error percentage as follows:

Percentage Error = [(Actual Value - Estimated Value)/ Actual Value] *100 %

Percentage Error using PSECOMO Model = [(21.5-25.15)/21.5]*100 % = **-16.97%**

Percentage Error using non-PSECOMO Model = [(21.5-26.89)/21.5]*100 % = **-25.06%**

Thus, it can be seen that productivity factor contributes for better cost estimations.

SystemStar can help in generating various reports like cost driver report, size driver report, effort report, structure report, size summary report, reuse report, activity report, equation report etc. for the sample project. Detailed report as obtained through SystemStar tool, is as shown in figure 4.

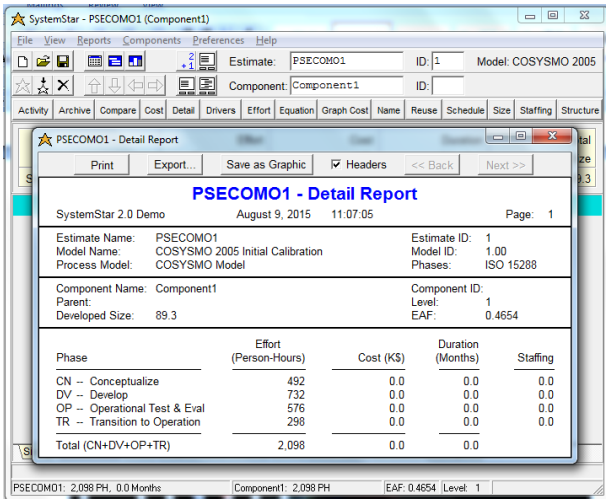

Fig. 4 Detail Report of PSECOMO

One of the key objectives for PSECOMO is to avoid the use of highly redundant parameters as well as factors which make no appreciable contribution to the results. In order to achieve this, four variations of the full model were tested to arrive at the final model that met all of the accuracy, parsimony, constructiveness, and simplicity objectives previously defined.

6. CONCLUSION AND FUTURE WORK

The paper concludes that the Delphi survey through a well formed questionnaire plays a significant role in the justification of the various cost and size driver's weights and thus development of PSECOMO. Also, a sensible and worthy data collection from different types of system engineering projects and then the analysis of that information is an important phase of the PSECOMO modeling. Introduction of the Productive parameters viz. Productivity by individual and Productivity by Team are expected to assist and achieve the aim of the proposed work model.

In order to determine the predictive power of the model it is to be validated through the use of statistical techniques. Model Verification and Refinement has to be done. Also the calibration of model has to be done by using it for a large number of data sets corresponding to a variety of system engineering projects as well as with the help of calibration tools. Feedback is taken by using excel workbook and analyzed. ***Calico*** Calibration tool can be used to calibrate the PSECOMO.

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