# A process centred virtual approach to support cost estimating along product life cycle

José Rios[1], Rajkumar Roy[1], Dolors Planas[1], Fabrizio Cochi[2], Dale Shermon[3], Shamraz Razzaq[3]

[1]*Cranfield University, Cranfield, MK43 0AL, UK, j.rios@cranfield.ac.uk & r.roy@cranfield.ac.uk*

[2]*Centro Ricerche FIAT, Str. Torino 50, 10043 Orbassano (TO), Italy, fabrizio.cochi@crf.it*

[3] *PRICE Systems, PRICE House, Meridian Office Park, Osborn Way, Hook, Hampshire, RG27 9JY, UK, dale.shermon@PRICESystems.com & Shamraz.razzaq@PRICESystems.com*

**Abstract**

The application of engineering practices and scientific principles to the creation of cost estimates along a product life cycle is one of the basic aspects of Cost Engineering. Cost estimates are used as fundamental criteria to make design decisions in the development stage and also to make business decisions in collaboration between OEMs and their supply chain. The achievement of an estimate requires experience and knowledge of different techniques and methodologies. Key aspects on its creation are the adoption of a cost estimating process, the availability of the needed data and the proper management of the information used during the process. The collaboration between the OEM and its supplier can be facilitated by having a better common understanding of how the cost estimates have been created. The cost estimating process used is then a fundamental piece of trust. In this context, V-CES project has developed a set of virtual tools and services around cost estimating processes to support the creation of cost estimates, the improvement of competences of the Cost Engineering Community, and the common understanding on cost between OEMs and their supply chain. The main purpose of this paper is to present the research conducted in the definition of cost estimating processes and the virtual solutions developed around them.

**Keywords**

Cost Estimating Processes, Product Cost Estimating, Virtual Cost Estimating, Cost Engineering

## 1 Introduction

Cost engineers and estimators are responsible for creating 'cost estimates' that are used as criteria to make business decisions. However, predicting the cost of a product is a challenging task. The achievement of an estimate requires a lot of experience, data, knowledge and skills of different techniques and methodologies. In this context, Cost Engineering (CE), the discipline where cost estimating is included in, is essential for survival of many companies.

However, there is a lack in the formalization of cost estimating methods and their integration within the design process. In many cases, designers were not directly involved in the cost estimating activity, and when requested, the cost estimates were performed by other personnel and by the time a cost estimate was available the design solution could have changed or been finally adopted. Quoting [Greves, Joumier, 2003]: "*The alternative offered by cost engineering is to have cost information available when design choices are being made, so that they will be made in the knowledge of approximately what the different potential solutions are likely to cost. This awareness of the likely cost is essential to be able to make effective cost/benefit trade-offs.*" Cost estimates have to be available at the right time, and provide the appropriated level of accuracy for the design stage where they are used. The accuracy of an estimate depends heavily on factors such as: who created the estimate, how the estimate was done, and which data were available at the time of its creation. These factors also depend on the product design stage where the estimate is developed [Layer et al., 2002], [Roy et al., 2003].

The process of creating a cost estimate is a key element as it is recognized by industry. This has led many organizations to promote and distribute cost engineering practices, and even data, with their suppliers to share understanding of cost and to achieve cost-effective performance. In addition to the efforts made by big companies, professional bodies and associations are also developing specific programmes to enhance cost engineering expertise, practices and competences. In Europe, the development of cost engineering competence is being addressed mainly by OEMs as part of their supply chain management improvement. The adoption of a common top level process to create cost estimates is perceived as a good initiative to enhance the accuracy of the estimates and the common understanding.

The importance of the CE professionals' competence has been recognized as a key aspect for many organizations. Training in CE is mostly available in the form of presence training, and the cost estimating process is not used as the guiding path to train professionals. In this context, V-CES project brings a Web based prototype solution based on three cost estimating processes: parametric, analogy and detailed. It targets professionals working in the manufacturing sector (automotive, aerospace, semiconductor equipment). The ultimate goal is to provide a collaborative web based environment where professionals and companies could exercise Just-In Time training, estimating and consulting directly related to cost estimating practices.

V-CES is a two years project funded by the European 6th FP for R&D. The consortium is made up of five partners: IZET, Cranfield University, C. R. FIAT, PRICE Systems, and DAS GmbH.

## 2 Research objectives and methodology

The definition of cost estimating processes and practices could depend on the kind of product, when in the product life cycle the estimate is done, who creates the estimate, the purpose of the estimate, the accounting practices of the company, etc. Considering this facts, the research questions we decided to address were:

1. Does it exist any way to define a cost estimating process independently of these factors?
2. Could the explicit definition and agreement on a cost estimating process be used to support the trust between OEMs and their suppliers?
3. Could a cost estimating process be used as the centre of training cost estimating professionals to enhance current practices in industry?
4. What kind of virtual framework would support the training needs of those professionals?

To address these questions, a set of research tasks were defined (Figure 1):

- Definition of Cost Estimating Processes - parametric, analogy and detailed.
    - Identification of the level of detail expected from industry.
    - Identification of trust building between OEMs and suppliers.
    - Identification of best practices.
- Analysis of training practices and needs in industry.
- Analysis of virtual frameworks for training.
- Development of a process centred e-support solution for cost estimating. Test cases and workshops are used to validate and improve the results produced.

The cost estimating processes are a reference way to create cost estimates, and in consequence allow comparing and validating them. This could be used as an element to build trust between organizations, e.g.: along the supply chain. Using the processes to train cost estimating professionals would help to improve the cost estimates creation, the common understanding and in consequence the trust between the professionals involved in any negotiation process. And it is in this point where the output of the activity A1 becomes the fundamental element of the V-CES project and of the activity A4 in particular.

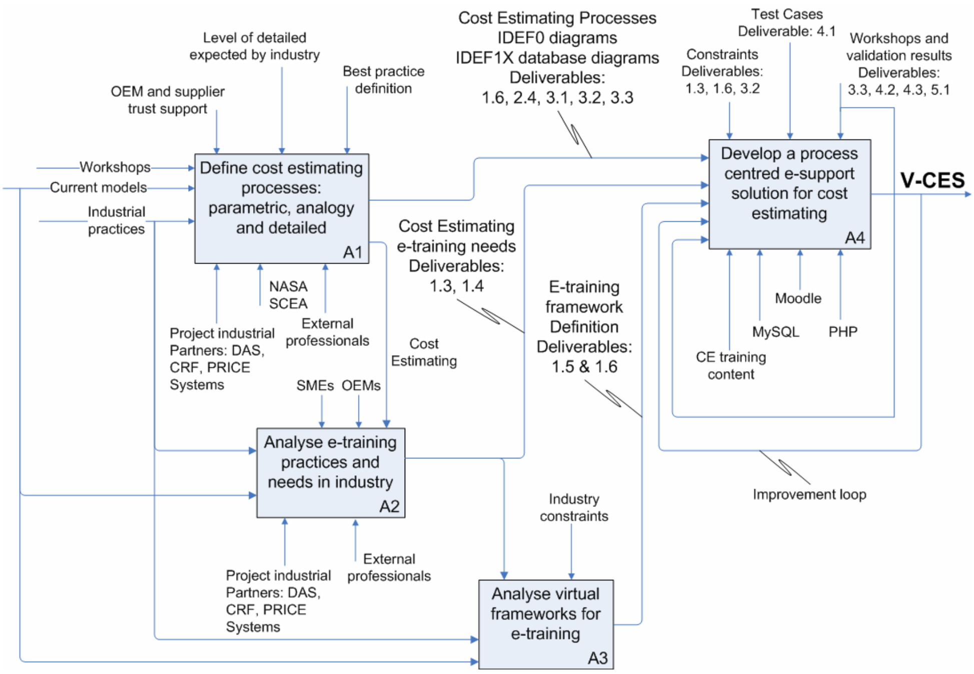


Figure 1. V-CES research methodology.

## 3 Cost estimating processes as a best practice

The definition of the cost estimating processes is the key to this research. A preliminary definition of the three cost estimating methodologies: Parametric, Analogy and Detailed were created based on the models proposed by NASA [NASA 2004], SCEA [SCEA 2003] and the Cost Engineering Capability Improvement Model [Lewis, Pickerin, 2001]. The processes were documented in a questionnaire and distributed among the project industrial partners and external cost estimating professionals for comments, amendments and validation. There were an initial number of responses collected that demanded a later interview with the people involved to gather fully the comments and to complete the first validation step. In a second validation stage, workshops with experts were also conducted. The validated processes are deployed in a web based tool called: e-Mentor accessible in the site: www.v-ces.com.

The creation of a cost estimate using any of the three methodologies demands the storage of the data used for its documentation. The definition of the data structure needed to support the processes was done using IDEF1X as data modelling technique.

### 3.1 Best practices definition

The industrial validation of the cost estimating processes led to the adoption of the ‘best practice’ concept: “a proven and repeatable way, method or technique for achieving a desired result, which has been successfully applied to real industrial situations” [V-CES D3.2 2005]. There are many elements to be considered for qualifying a particular process as a ‘best practice’, such as: experience, literature, knowledge, and real evidences. The best practices in cost estimating are not explicitly described as such in literature or in the industrial environment. In general, we find ‘*common use practices*’, experience of senior engineers or hints. The first step was to formalize the concept of a best practice and secondly to identify suitable criteria to define them.

The industrial partners of the project collected external and internal practices. Each partner in its specific industrial sector: CR Fiat (automotive), PRICE Systems (aerospace) and DAS (semiconductor equipment). The practices were analysed and grouped in a top level common practices and in three clusters of cost estimation: analogy, parametric and detailed. The reason for this clustering resides in the fact that the main differences were recognizable in the cost estimating methodology rather than in the different sectors that adopt them.

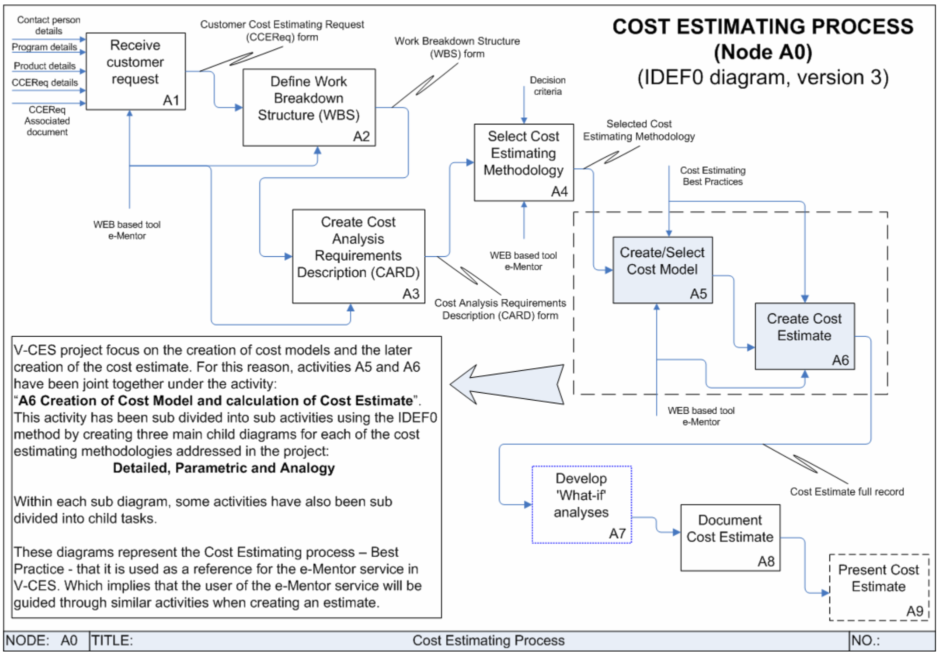


Figure 2. Simplified IDEF0 diagram of the top level cost estimating process.

## 3.2 General cost estimate top level best practices

Cost estimates have different purposes, being an input to decision making in project phases. When considering the management perspective of a project, cost estimates are a valuable tool, since for instance they provide the information to determine the capital investment of the project. With this idea in mind, there is a set of best practices to follow when creating a cost estimate that are independent of the cost estimating technique to be used [Hamilton, Westney, 2002]:

1. Definition of the scope of the work.
2. Definition of the project execution plan.
3. Determination of the estimating data and the cost estimating methods to be used.
4. Allocation of qualified human resources.
5. Calculation of cost of major elements.
6. Determination of cost of design, project management, start-up and owner costs.
7. Normalization of data, determination of exchange rates and escalation of future costs.
8. Determination of contingency to be applied.
9. Conduction of intermediate and final checks of the estimate.
10. Comparison of cost with similar projects.

These top level best practices were considered in the top level tasks (activities A1 to A9) or in the definition of the three methodologies: analogy, parametric and detailed (activities A6.x). For instance, the BP1 "Definition of the scope of the work" is captured in the task A2 Define Work Breakdown Structure (Figure 2). The BP7 "Normalization" is included in each methodology and it should apply to the cost data used (i.e.: activity A6.4 in the Parametric Cost Estimating - Figure 3, and A6.3.5 in the Analogy Cost Estimating - Figure 4) [V-CES D2.4, 2005].

## 3.3 Parametric cost estimating

This methodology is based on the identification and mathematical formulation of relationships between cost and product parameters (cost drivers), known as Cost Estimating Relationships (CERs). This approach demands the access to historical data and assumes that the relationship will continue in a similar way in the future. Figure 3 represents the main tasks to conduct when creating a parametric cost estimate (Node A6 Create Cost Model and Calculate Cost Estimate).

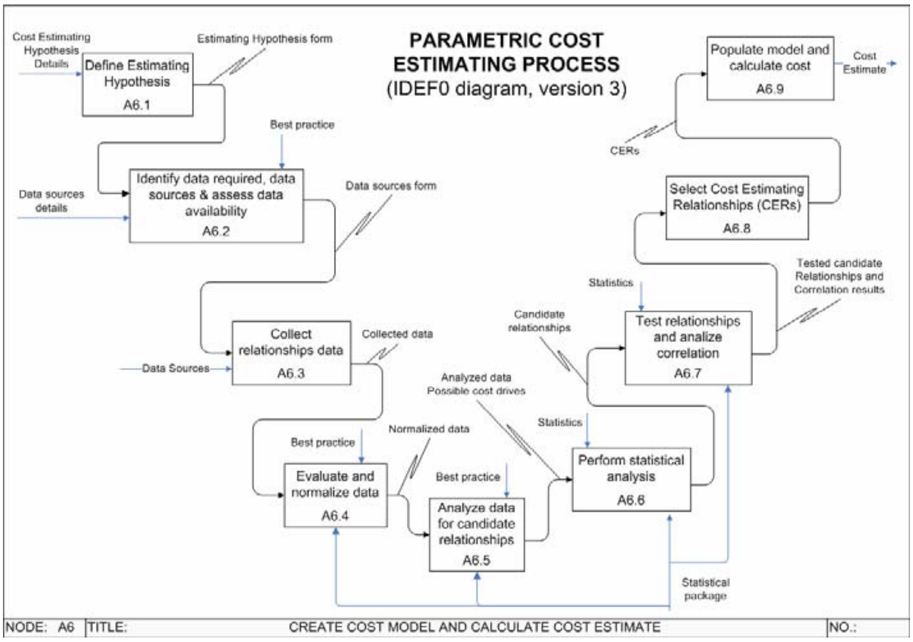


Figure 3. Simplified IDEF0 diagram of the parametric cost estimating process.

## 3.4 Analogy cost estimating

Analogy or case-based cost estimating demands to identify a reusable case and similarities and differences. It requires defining adjustment factors to account for complexity, both technical and/or physical differences between components. The proposed complexity practice considers differences in terms of: requirements, design solution adopted, design solution maturity, and manufacturing technology readiness for the solution. Possible productivity improvements related to the production facilities and resources are considered separately and as optional tasks to conduct. Similarly with the possible cost improvement slopes or learning curves (Figure 4).

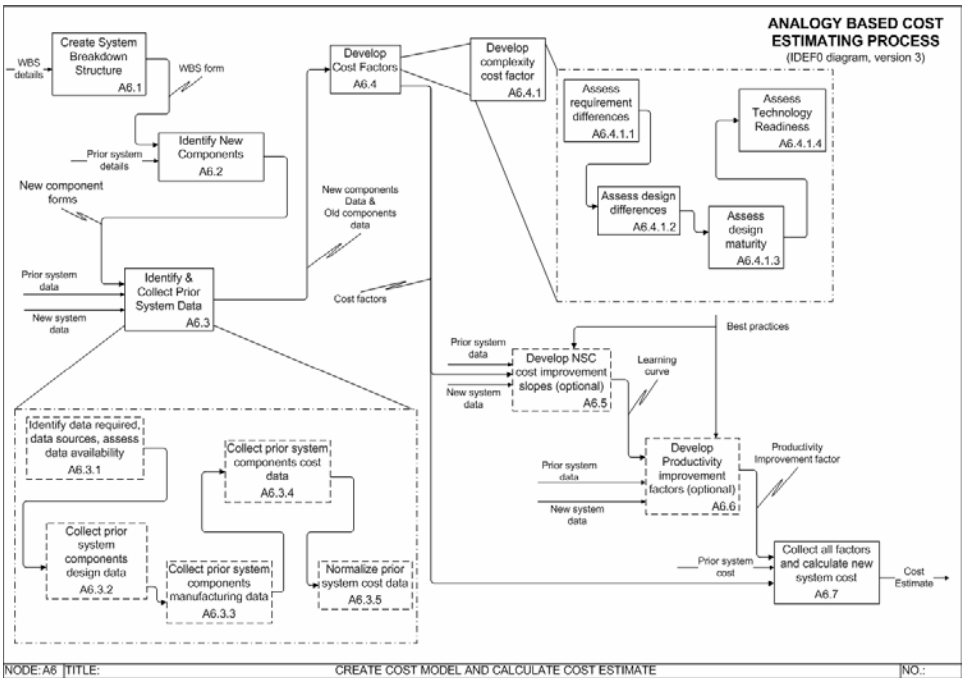


Figure 4. Simplified IDEF0 diagram of the analogy cost estimating process.

## 3.5 Detailed cost estimating

Also known as bottom-up, it demands access to specific cost data, and the allocation of the cost elements: labour, material and equipment. In the case of V-CES it is applied as a Unit-based cost system, and it is characterized by a thorough, detailed analysis of the work packages, components and processes related to them. For each work packaged, the subsystem or components to consider have to be defined. For each component, the material cost is calculated. Then for each process defined for the component its costs are calculated: labour cost, equipment cost and overhead cost. The application of this methodology demands knowing: labour rates, material prices, machinery hourly cost and overhead costs [V-CES D2.4, 2005].

### 3.6 Best practice validation

The processes validation was divided in two stages. The first stage focused on the processes definition and used the responses to a questionnaire and interviews with experts as input. Led by CR FIAT, the second one focused on identifying the processes as 'best practices' (with two approaches: empirical and objective) and in evaluating their deployment in a web tool (Figure 5).

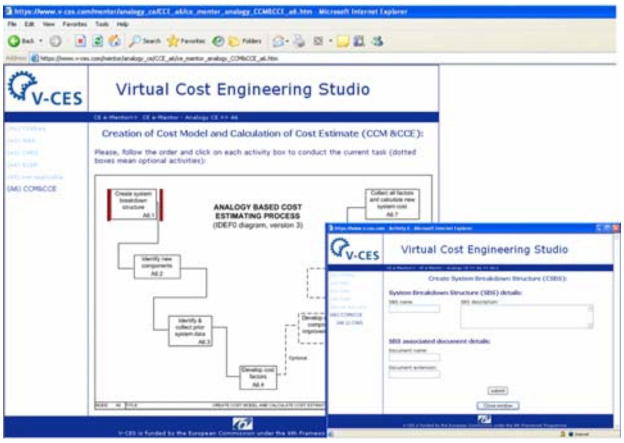


Figure 5. Web based cost estimating tool: e-Mentor.

In the objective approach, the evaluation of the practices is done by means of a set of measurements criteria: time needed to complete an estimate, data availability, data coherence, data significance, easiness of recovering and interpreting hypothesis, output accuracy of the estimate, resources needed, complexity of the practice, required skills, repetitiveness, organisational commitment and synergy with other departments.

The empirical approach is based on the knowledge owned by qualified Cost Engineers. During a workshop the processes were presented and discussed with them to identify gaps, improvements, to document the rationale. As a consequence of the best practice validation process several improvements were identified to be incorporated in the second prototype of the cost estimating process web based tool deployment (e-Mentor) [V-CES D3.3, 2006].

## 4 Supporting collaborative product cost estimating

### 4.1 Developed framework

As it was initially mentioned, apart from data, the creation of a cost estimate demands:

- Experience to: identify sources of information, evaluate and engineer data, identify the cost estimating method to use, create a cost model, and apply a cost estimating process.
- Knowledge and skills in: cost estimating techniques, processes and practices, cost model elaboration and analysis, data mining and normalization, and statistics.

The technical solution adopted addresses these aspects (Figure 6) [Roy, Rios, 2005]. Experience is targeted by the e-Community and the e-Mentor, knowledge and skills are targeted by the e-Training and the e-Mentor, and data is targeted by the Database but also some data is expected to be gathered through the e-Community. Professionals have to use just a Web browser to access the collaborative framework [Roy, Rios, Hussla, Hansen, 2005] [Roy et al. 2005].

The cost estimating processes, qualified as ‘best practices’, are the kernel of the framework:

- E-training by doing. Developed in the V-CES e-Mentor, and where the cost estimating tasks drive the training process.
- E-training by lectures. Linked to the cost estimating processes and available in the form of e-courses (V-CES e-Training).
- E-training by discussions. Available in the V-CES e-Community, where synchronous and asynchronous communications among trainees and mentors can take place.

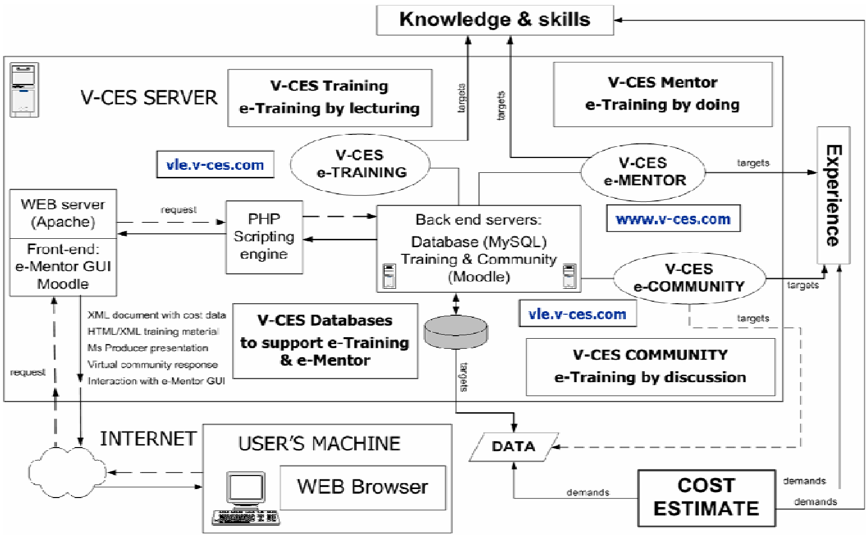


Figure 6. V-CES developed framework.

## 4.2 Testing and validation process

The testing of the V-CES prototype was led by PRICE Systems based on a number of categories of test in each framework component (Figure 7). A set of test cases were written to be followed and a defect report was attached to them to record any malfunction in the prototype. The test cases were conducted by the project partners and by external companies. Due to the limited time available from the external companies, a team member was present to assist in covering the whole spectrum of the three estimating methods [V-CES D4.2, D4.3, 2006].

| | 01 – Database | 02 – Cost Engineering Mentor | 03 – Virtual Engineering Community | 04 – Help Desk |
|---|---|---|---|---|
| A. Functional | 01 – A | 02 – A | 03 – A | 04 – A |
| B. Acceptance Test | 01 – B | 02 – B | 03 – B | 04 – B |
| C. Feature Help | 01 - C | 02 – C | 03 – C | 04 – C |
| D. Windows GUI Standard | 01 – D | 02 – D | 03 – D | |
| E. Operating System | 01 – E | 02 – E | 03 – E | |
| F. Regional Settings | 01 – F | 02 – F | 03 - F | |
| G. Input Field Testing | 01 – G | 02 – G | 03 – G | 04 – G |
| H. Error Handling | 01 – H | 02 – H | 03 – H | 04 – H |
| I. Security | 01 – I | 02 – I | 03 – I | 04 - I |

Figure 7. Test matrix.

As a consequence of the testing results a set of errors, and related actions (grouped as minor, medium and major) to be incorporated in a second prototype were defined. For the e-Mentor tool the main defined actions are related to: functional aspects such as: database consistency, mandatory fields and activities precedence; improvements in error handling, equations and graphics, and graphical user interface [V-CES D5.1, 2006]. Together with the defect reports, three cases studies: detailed for automotive (connecting rod), analogy for semiconductor equipment (abatement system), and parametric for aerospace (airframe) are used in the improvement loop to produce a second prototype (Figure 1).

## 5 Conclusions

The paper has presented the process centred solution adopted in the web based tool developed in the V-CES project. Validated both internally and externally and qualified as ‘best practice’, it represents an innovative approach to enhance cost estimating collaboration in the supply chain, and the training of cost engineering professionals. The approach adopted and the prototype developed respond to industrial needs, but there are several improvements to be incorporated. Briefly, it can be concluded that:

- The process centred approach adopted is quite innovative in terms of research and the solutions commercially available, and it complies with the customer requirements of better understanding, visibility and transparency in the creation of cost estimates.
- The spread and common understanding of cost estimating techniques can be improved by a web based tool to support and train professionals.
- Cost estimating processes are a key element to improve the common understanding and trust among companies when negotiating contracts. Helping to enhance the collaboration between OEMs and supply chain.
- The e-training services developed in the project are sufficient in terms of the requested service from the professionals. However, further work is still needed to enhance the current prototype and to incorporate a wider range of best practices in all the different tasks.

**Acknowledgement**

This work is funded by the European Commission through IST Project V-CES: Virtual Cost Engineering Studio (No.: IST-2003-507041). The authors wish to acknowledge the Commission for their support. We also wish to acknowledge our gratitude for their contribution to other members of our organizations and project partners: Decision Engineering Research Team at Cranfield, CR FIAT, PRICE Systems, DAS and IZET.

**References**

Greves, D; Joumier, H: Cost Engineering for Cost-effective space programmes, ESA bulleting 115, August 2003.

Hamilton, A C; Westney, R E: Cost estimating best practices, AACE International Transactions, EST.02, 2002.

Layer, A; Ten Brinke, E; Van Houten, F; Kals, H; Haasis, S: Recent and future trends in cost estimation, Int. J. Computer Integrated Manufacturing, Vol. 15, No. 6, 2002, pp. 499-510.

Lewis, D; Pickerin, H: A capability improvement model for cost engineering. A white paper on the EACE Cost Engineering Capability Improvement Model (CECIM), EACE, 2001.

NASA: National Aeronautics and Space Administration - Cost Estimating Handbook, 2004.

Roy, R; Rios, J: Virtual Cost Studio (V-CES): a framework for cost engineering services, Proceedings of the 11th Intl. Conf. on Concurrent Enterprising, ICE 2005, Munich, Germany, June 2005, pp. 497-500.

Roy, R; Rios, J; Hussla, I; Hansen, L: Virtual Cost Engineering Studio (V-CES): the challenges of a Just-In Time service for cost engineering professionals, Innovation and the Knowledge Economy: Issues, Applications, Case Studies, vol. 2, Intl. Conf. e-Challenges, Ljubljana, Slovenia, October 2005, pp.1477-1485.

Roy, R; Rios, J; Sagoo, J; Hussla, I; Hansen, L: Virtual Cost Engineering Studio (V-CES): a new service for cost engineering professionals, Strengthening Competitiveness through Production Networks, 6th FP EU, ICT for Enterprise Networking, 2005, ISBN: 92-894-9924-9, pp. 91-101.

Roy, R; Souchoroukov, P; Kopponen, H: Information requirements for cost estimating in the automotive industry, The 8th Annual ASME Design for Manufacturing Conference, Chicago (USA), September, 2003, Paper Reference: DETC2003/DFM-48153.

SCEA: The Society of Cost Estimating and Analysis – Parametric Estimating Handbook, 3rd Ed., 2003.

V-CES Consortium D3.2: Report on best practices formalisation, January 2006.

V-CES Consortium D2.4: Report on prototype cost engineering mentor and V-CES platform, September 2005.

V-CES Consortium D3.3: Report on internal validation, January 2006.

V-CES Consortium D4.2: Test procedure on components of the V-CES prototype, January 2006.

V-CES Consortium D4.3: Intermediate best practice report, January 2006.

V-CES Consortium D5.1, Report on the analysis of the field test results, February 2006.