Implementing a robust cost estimating process

By H. Joumier Head of ESA Cost Engineering
European Space Agency – ESTEC, Noordwijk, The Netherlands
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1. Introduction

How do cost estimating entities bring value in an organisation and how can survive such groups through time?

These questions may not have easy answers and many counter-examples of short existence are observed both in industrial companies and procurement agencies. They tend to resurface later on in different forms but in most of the cases this reshuffling is accompanied with significant loss of experience, qualified personnel or even loss of reference data and cost models.

Their robustness is then a matter of concern in the profession and for any organisation intending to preserve its investments. It should be remembered that a lot of the experience of the cost estimators is coming from confronting past estimates with received prices or cost at completion. This, in the aerospace sector, takes several years before it occurs so the survivability of these entities is of paramount importance to complete the expertise acquisition cycles.

This paper is not going to talk about cost models as such but will rather focus on all peripherals activities and processes that allow the cost modelling entity to be trusted and recognized within its own organisation. This analysis is based on how the ESA Cost Engineering has treated this matter and describes key concepts put in place over the past few years.

2. The implementation of the Cost Engineering function

There is no standard place where to find the Cost Estimators within an organisation and this is certainly one of the main reasons of its fragility.

The most unstructured way to practice cost estimating is quite often seen in small companies where study/project managers or the head of the projects directorate will intermittently practice cost estimating mostly relying on their own expert judgement or the brainstorming results from their close circle of collaborators. Methods used are usually limited to global and subjective analogy to previous projects. Reference data repository exists in embryo format, usually limited to few spreadsheets.

Larger organisations tend to develop more structured cost estimating entities but here again there is no evident place were they sit. The cost estimating resources may be centralised or scattered into different operational branches or a combination of both.

Cost estimating lies somewhere in the triangle defined by Finances, Procurement and Technical poles and this implementation may vary along time with organisations reshuffling.

As a result there is no standard definition of the cost estimating mandate to refer to.

An additional difficulty resides in the fact that Cost Estimating is inherently dealing with predicting the future on a very sensitive and usually highly controversial issue, namely: the money.

For all these reasons, cost estimating requires maybe more than for well-established functions to assert its role within the organisation and to demonstrate its added value.

Let us see how a Cost Engineering entity can take its destiny in hands and preserve its longevity.

The generic road map of any new cost estimating entity should therefore look as follows:

1. Assemble a seed-team of skilled human resources;

2. Initialise the collection of reference data and start developing a properly structured and normalised dataset as soon as possible;

3. Provide complete analysis including cost risk assessments;

4. Define deontology, services and stick to these lines;

5. Benchmark cost estimates and assimilate lessons learned;

6. Expand up to operational level by completing resources (data references, models, estimators) based on success stories.

This paper is focusing on points 2, 3, 4 and 5 of this list by showing the solutions put in place by the ESA Cost Engineering team.

3. Database build up monitoring

3.1. Source of data

ESA is placing most of its big contracts as Firm Fix Price or Ceiling Price to be converted to a Firm Fix Price. As a result, proposed prices when open competition properly applies are very representative of the fair economical effort to realise the projects.

Such data is the primary source of information to build the database of references for the following reasons:

• Economically valid source of financial data as described above;
• Fresh information i.e. related to contemporary technologies;
• Harmonised set of technical, programmatic and financial data.

Collecting the details of these prices in a structured and recurring manner has lead ESA to develop and maintain an application software called ECOS[1]. This application has been operational for more than 20 years and has gone through a major upgrade at the end of the year 2006. Its use is made mandatory through the Special Tender Conditions of all Invitation to Tender and Request For Quotation of projects intended to be worth more than 20 Meuro. The application is closely simulating the contractual flow between upper-tiers and sub-contractors at all levels of the contracting arborescence.

Figure 1 - The ECOS application allows aggregating the financial flows of the whole procurement chain

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[1] The reader can refer to ECOS Help Desk (ecoshelp@esa.int) to know more about ECOS

To answer the fundamental need to collect the data in a systematic manner, the WBS, being the basis for the CBS, is built on the basis of a dual hierarchical structure:

- The Product Tree using a free but still hierarchical code
- The Support Functions built according to a predefined code

The Support Functions have been reviewed in 2006 in a joint exercise involving the whole ECOS users' community.

In less than a year, mainly using Web forum technology, the set of Support Functions has been revised, completed and a whole dictionary defining each of the elementary activities has been created[2].

3.2. Data Entry Process

ECOS proposals are therefore regularly collected and flown into the main ESA data repository called CEDRE

CEDRE is a server based relational database built under MySQL/Java script technologies.

Some routine processes allow injecting ECOS files into CEDRE. Once this is done the user complements the records by allocating the CBS elements to classes of product together with a set of appropriate keywords that allow easy information selection and retrieval

The programmatic information and additional features such as pictures of the product or parametric models parameters are also associated to the records.

The collection and processing of reference data is often perceived as a tedious task. Still the rigor and the care given to this exercise is instrumental to the quality and accuracy of the cost estimates that will result either from the direct reuse of the data for analogy purposes or indirectly after building cost estimating relationship based on.

The IT tools will not do everything. There is a naïve vision in some minds that once the software environment has been developed and the information paths defined then the information will automatically flow into the database and the CERs will be computer-generated without human intervention.

The experience shows that this activity requires human interventions at all stages properly defined via management procedures and associated performances indicators. This will give a chance to maintain high quality standard together with optimised resources dedication.

The core idea is that building up the reference database is a "cultural" exercise that contributes to the cohesion and the image of the team. Each cost estimator has its own sensitivity. It is well known that two cost estimators will not produce exactly the same cost estimates for the same case. But how large a difference can be allowed? Preferably, as minimal as possible. One fundamental element in establishing the credibility of a cost estimators team is that the result of the cost estimate should not vary significantly according to who is performing it. In such conditions, sharing common views on the reference data is a necessary starting point for harmonising the expertise.

Consequently, the complete data entry process should never be the case of an isolated person. At a point in time the information needs to be presented to the rest of the Team that will scrutinise it. This is what we call "endorsing" the data.

The Endorsement process needs to be properly defined and scrupulously followed because it will guarantee the quality of the dataset.

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[2] The Support Function dictionary is available by application to the ECOS Help Desk

We have defined what we call the Endorsement procedure and have added specific status field to our database, as displayed on Figure 2, to monitor the Endorsement status. We distinguish 3 status levels:

Non endorsed: The data has been entered but has not been peer-reviewed and is not yet declared ready for this review.

Ready for Endorsement: When the cost estimator in charge of the data entry considers that he has finished the work, he asks one of his colleagues to review the new entries as for endorsing it. This colleague will eventually make some comments and, after discussing the points with the data enterer, will finally declare the data Ready for Endorsement. This pre-endorsement allows minimising the personnel involved in skimming out the first degree anomalies.

Endorsed: When a new set of entries is declared "Ready for Endorsement", The Team will scrutinise the data and an endorsement meeting gathering the entire group will be called. Remaining hanging points found will be discussed in session. Short term actions will be decided if the case cannot be settled real time during the meeting. The cost items attracting consensual agreement will be declared "Endorsed".

For practical reasons a forth status has been identified to deal with the historical records, entered into the dataset prior to the implementation of the Endorsement procedure. These Historical records are deemed to go through an Endorsement process at a point in time.
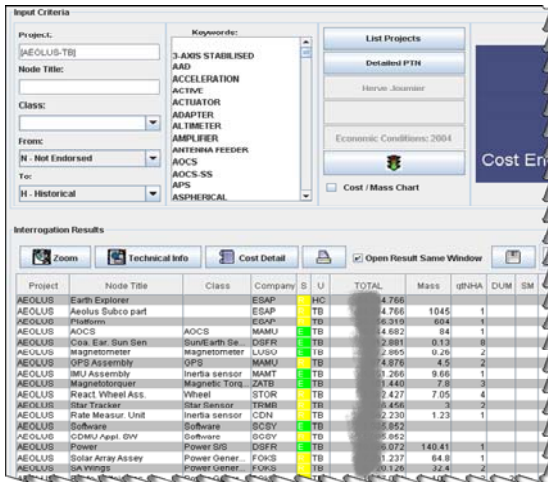

Figure 2 - Screenshot of the CEDRE database showing some yellow and green flags of the endorsement status

3.3. Tracking Data Entry Progress

If the endorsement procedure guarantees a certain quality level of the database, still one must make sure that the works are carried out within a reasonable time-frame and man-hours spending.

As earlier mentioned, Data Entry is a tedious exercise, far from the spotlights, so this task is known to attract less interest from the cost estimators. Still, the build-up of a clean database is a major prerequisite for the quality of the estimates.

Management tools exist to turn boring tasks into more exiting ones. Whatever the chosen one, recognition of success and achievement is the ultimate step not to skip to ensure adhesion of the team to the process.

The method that ESA has selected is the well established Earned Value Management[3]. The main reason is that it is particularly suited to this kind of situation considering the good level of definition and the repetitive aspect of the tasks to be performed for each project. Another important reason is to "sell" the EVM principles into the European Space sector where it is not yet so developed. Applying it first to ourselves is considered to be the most convincing way to promote it.

A typical Data Entry action consists of processing the ECOS proposal and associated programmatic/technical data of a satellite implementation phase. This usually takes a few days to a few weeks depending on the quality of the data and the size of the project. Each data entry action is identified as a "project" for which a "Baseline" is established by discarding the cost items that will not be subject to further data entry[4] than ECOS financial data import.

The Table 1 here below shows a "dream case" example of data entry EVM where the performance both time-wise and cost-wise are going pretty well since at mid term the work achieved is slightly more than 50%. This gives hope that the data entry will be completed in time or better and within the allocated hours. To be noted that 32 cost items have been discarded for data entry purpose (188-156).

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The BAC (Budget at Completion) has been established on the basis of 1.5 hours per cost item for the 95% that represent the cost item level activities.

Some standard weighting factors have been defined for each of these elementary activities both at project level and at cost item level.

A flag is associated to each cost item to integrate it into the baseline.

There is an internal routine that counts if elementary events have occurred for each of the cost items so the physical progress is permanently self-computed by the application.

The ACWP information is extracted from the ESA internal time sheet system

Considering the small size of the "Project", the BCWS follows a linear approximation.

By doing so, the EVM report can be ran at any time and provide a clear status about the data entry action: when is it foreseen to be completed and for how many hours spent?

CEDRE Data Entry EVM					
			Data entered by	HJ	
Project Name	Project A			Status date	15/04/2007
			Weight	%completed	%achieved
Project level	Create new Project in Database		1%	100%	1.0%
	Import ECOS file		2%	100%	2.0%
	Establish Baseline		2%	100%	2.0%
		items completed	Start	planned	
			15/03/2007	15/05/2007	
Cost Item Level	Associate class	150	5%	96.2%	4.8%
	Associate Keywords	130	5%	83.3%	4.2%
	Associate pictures/documents	125	10%	80.1%	8.0%
	Enter Mass	140	5%	89.7%	4.5%
	Enter Class Mandatory parameters	88	15%	56.4%	8.5%
	Enter Programmatic information	120	10%	76.9%	7.7%
	Enter Design parameters	68	10%	43.6%	4.4%
	Complete non-endorsed status	60	10%	38.5%	3.8%
	Ready for Endorsement status	40	10%	25.6%	2.6%
	Endorsed status	0	15%	0.0%	0.0%
				Physical Progress	53.4%
Total number of Cost Items	188	SPI	SV	BCWS	BAC
Number of Baseline Cost Items	156	1.05	6.4	127.0	250
Comments:		CPI	CV	BCWP	ACWP
		1.07	8.5	133.5	125
			ETC	EAC	forecast
			116.5	241.5	12/05/2007

Table 1 - Data Entry EVM typical example

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[3] The reader not yet familiarized with EVM principles terminology and acronyms may consult among many other web resources : http://evm.nasa.gov/

[4] Typically cost provision for Ground Support Equipment (GSE) is not associated with an exploitable technical definition at proposal stage.

More global indicators can be generated at overall database level: How complete is the database? What is the overall maturity of the database i.e. what are the respective percentages of non endorsed/ready for endorsement/endorsed records? Feed-back on how many average hours per cost item are required to perform data entry?

The existence of such progress control improves the confidence into the value for money that an organisation puts in the development and the maintenance of the database, and as such contributes to establish the credibility of the cost estimating entity that applies such process.

4. Class of Cost Estimates

More and more, cost estimating entities are internally charging their services to the beneficiaries.

This establishes a customer-supplier relation deemed to maintain a high quality standard of delivered services. The purpose of this paper is not to discuss the goodness of this approach but to show what formalism is then best suited to deal with expectations of both parties under this working arrangement.

Typically very early and roughly defined concepts should require light estimates while committing on an implementation phase will need detailed and highly accurate cost estimates. Everybody understands that the time and resources needed to prepare these two very different types of estimates are not the same, but misunderstandings can be avoided by using classes of estimates that will show upfront in a very transparent manner what cost estimating accuracy will be reached for what expected effort.

Here is under the table of classes of estimates used by ESA and derived from AACE International recommended Practice No 17R-97:

Class of estimate	Primary characteristic	Secondary Characteristics			
	Level of Project Definition	Typical End Usage	Methodology	Expected Accuracy[1]	Preparation effort[2]
Class 5	0% to 2%	Screening or Feasibility Program preparation	Parametric and Analogy at preliminary system and assumed sub-systems levels; Several system level solutions. First global profiling of costs risks per risks contributors	4 to 20	1 per system
Class 4	1% to 15%	Concept Study or Feasibility inside or outside of the CDF	Parametric and Analogy on a preliminary sub-systems and equipment level. Trade-offs at sub-systems level. Cost risk distributions per CBS elements. Use of Risk register when available.	3 to 12	2 to 4 per system architecture
Class 3	10% to 40%	Phase C/D Programme Declaration	Parametric and Analogy on a refined sub-systems and equipment level. Cost Risk assessment based on CBS distributions built-up per contributors. Use of risk register for non-CBS elements.	2 to 6	3 to 10 per system architecture trade-offs closed
Class 2	30% to 70%	System PDR	Parametric and Analogy on a frozen equipment level. Integration of negotiated prices. Cost Risk assessment based on CBS distributions built-up per contributors. Use of risk register for non-CBS elements. Implementation of Cost Risk Management.	1 to 3	5 to 20
Class 1	50% to 100%	System CDR	Integration of negotiated prices Analogy and Bottom up analytical estimate for the remaining part. Cost Risk assessment based on CBS distributions built-up per contributors. Use of risk register for non-CBS elements. Cost Risk Management in place.	1	10 to 100

Table 1 - Definition of Classes

[1] The basis is the Class 1 accuracy. The numbers for other classes are a multiplying factor for calculating the expected accuracy. E.g if Class 1 is 5 % accuracy then Class 4 achievable accuracy will be in the range of 15 to 60%. More details are given in table 2
[2] The basis is the Class 5 effort.

Table 2 - The ESA Class of Estimates

More detailed metrics, based on class 4 estimates, define the time to perform the cost estimating activities as a function of the project magnitude and degree of complexity. Some corrective factors have been defined to account for the availability and quality of the reference data or the availability of the technical specialists for interviews.

Declared accuracy, based on class 4 estimates, depends on the degree of complexity and time to prepare.

This matured approach of the definition of service has proven to contribute efficiently in establishing the credibility of the cost estimating entity, even before producing any cost estimate figure.

5. Cost Risk Assessment

The need to complete cost estimates with cost risk assessment is a concept that has been well developed since the end of the Faster-Better-Cheaper era.

The ESA Cost Engineering has developed a cost risk assessment procedure and methodology that was first presented at ISPA 2006 in Seattle.

The Cost Risks Assessment method has been developed with the idea in mind to provide the Project Managers with a directly usable management tool for their projects rather than simply adding up layers of cost at the top of a core estimate.

5.1. Risks and Opportunities

The method identifies both Risks and Opportunities using the following definition:

Cost Risk: A cost risk is a potential future event with negative effect on cost containment which may occur or not.

Cost opportunity, contrarily to the cost risk, is a potential future event that may bring cost savings.

In both cases a proactive approach can be developed either to mitigate or even suppress the risk or on the other side trigger and exploit opportunities.

Risk analysis is too often limited to identifying risks and not opportunities. When doing so, the cost risk analysis may be perceived as a way to systematically inflate cost estimates and thus spiralling up the costs from one project to the next, ultimately decreasing their value for money. The right balance has to be found between the necessity to provide a complete and credible cost estimate i.e. not naively optimistic or not addressing the whole scope and, on the other hand not to inflate it too much and artificially by excessive risk coverage and ignorance of opportunities.

5.2. Cost Risks contributors

The cost risks contributors have been defined according to the following criteria:

- Group the different risks placed under the responsibility of a particular entity (risk owner).
- Group together risks according to their characteristics and modelling behaviour.

Four families of cost risk contributors have been defined as follows:

- Cost Modelling Accuracy CMA belonging to cost estimators
- Design Maturity Margin DMM owned by designers
- Project Owned Events POE under the responsibility of the Project Manager
- External Project Environment EPE covered at Corporate level

Type	Short description	Characterization				Core Estimate	Risk owner
		Input Profile	Min	Most likely	Max		
DM	**Design Maturity**: accounts for cost growth induced by unseen complexities revealed during the progression into more detailed design. It is an entropic effect inherent to the design activity and, therefore has to be considered part of the Core Estimate.		Point estimate	Point estimate	Results from: TRL, confidence level of design, domain	YES, expressed as cost growth margin	Engineering team
CMA	**Cost Model Accuracy**: accounts for cost risk induced by uncertainties of methods and models utilised for the cost estimation. It has to be considered in the core estimate as error quota.		Given by statistical analyses	Point estimate	Given by statistical analyses	YES, expressed as error margin	Cost engineering
POE	**Project Owned Events**: (classic development risk-register items) account for cost risk induced by potential future negative events that may occur or not. Additionally cost opportunities will be registered as well. While negative effects to some extent can be mitigated by specific actions, opportunities need to be exploited. In either case the advantages have to be traded-off with the costs of mitigation/exploitation. Such costs have to be considered part of the core estimate, then.]	Risks	0	product of consequence and chance of occurrence	Worst case scenario cost consequence	NO, expressed by cost risk margin	Project Manager
		Opportunities	Best case scenario cost saving	product of consequence and chance of occurrence	0	NO, expressed by opportunity potential	
EPE	**External Project Environment**: accounts for cost risk or opportunities that originate from unfavourable project environment out of direct influence from the project manager. Otherwise, experience shows that in many cases this type of risk could be mitigated by upper level management decision. If such mitigation decision exists, the risk contribution can be discarded at no extra cost.	Risks	0	product of consequence and chance of occurrence	Worst case scenario cost consequence	NO, expressed by cost risk margin	Mainly Executive level Management
		Opportunities	Best case scenario cost saving	product of consequence and chance of occurrence	0	NO, expressed by opportunity potential	

Table 3 - The Cost Risk contributors

5.3. Cost Risk sharing

The latest development of the ESA Cost Risks Assessment procedure has been to segregate the Contractor and the Agency's shares of risk among the different contributors' categories.

By doing so, we now define an aggregation level that corresponds to the expected price of the bidders before covering the project at Project Manager Level and then at corporate level.

5.4. Presentation of Cost Risks Assessment results

Besides the classical way of displaying cost-risk of a project in form of a cumulative s-curve, it is suggested to show a histogram with cost-risk margins by risk type[5].

The presentation per main risk contributors allows developing pro-activeness of the concerned actors. In addition the graphical format allows seeing at a glance the cost risk profile of the project; a business as usual telecom project is not deemed to display the same cost risks contributors' profiles than a state-of-the-art deep space exploration mission.
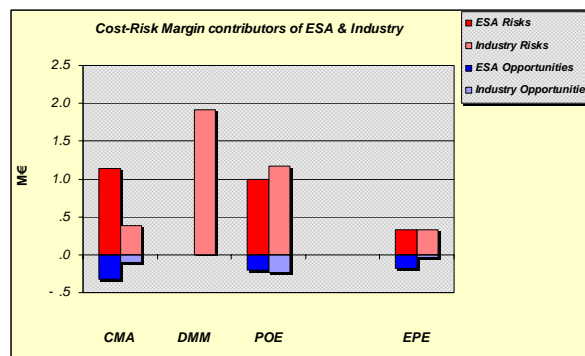

Figure 3 - The Histogram of Cost Risks provisions per contributors

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[5] See ISPA Seattle conference proceedings 2006 for more details about calculating contributors 'share of risk provision.

The Continuous Cost Risk Management can be smartly supported by the periodic comparison of such histograms over the time. The quantitative illustration of the risk/opportunity potential together with the clear assignment of responsibilities undoubtedly generates a very good motivation for improving the project cost efficiency.

The Cost estimate is presented in Table 4, according to the following layers issued from the exploitation of the histogram data of Figure 3;

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Details of the Point estimate		
Total Industrial Point Estimate		Estimate resulting from application of CERs
DMM		Provision for Design Maturity
CMA (Industry share)		Provision for cost estimating errors
Total Core Industrial Estimate		Price of the project without provision for feared events
POE (Industry Share)		Provision to cover risks owned by the Project, Industry level
EPE (Industry share)		Some EPE like Geo-Return may be tranferred to Industry
Total Industrial Cost Estimate		**This is the expected Fixed Price quotation from Industry**
CMA (Agency share)		
POE (Agency Share)		Provision to cover risks owned by the Project, Agency level
Total Agency Project level Cost		**This is the Project Manager budget responsibility level**
EPE (Agency share)		To cover impacts of political decisions
Total Agency Corporate level cost		**The amount to be considered into the Agency Corporate planning**

Table 4 - The three levels of the cost estimate

As a result, there is not one cost estimate but a cost estimate corresponding to each interlocutor level. It also allows understanding the common feeling that technical specialists tends to be optimistic or underestimating. In fact their reasoning stops at DMM level which is by the way the level at which they are expected to commit.

This three level analysis is:

- allowing to dialog with the Project Office and fixing cost target to industry;

- broadening the views of the Agency Project Manager to help him fix his own level of commitment vis-à-vis the Executive.

- Providing corporate level managers with useful quantitative information to build up corporate level risks provision.

6. Cost Estimating accountability

Because cost estimators rightly claim that the value of their work also depends on how independently they operate from the projects stakeholders, there must be a guarantee that this independency is not unduly used to produce biased estimates.

For this reason, cost estimators should systematically benchmark their estimates with estimates or committing prices from the counter-parts and must be ready to report on discrepancies in a rationale, transparent and structured manner.

Hereunder is illustrated how the ESA Cost Engineering carries out such benchmarking activities:

- Keeping a log of all estimates (produced and received from counter parts) and prices in a structured log called CLEAR (Central Log of Estimates for Accountability Records).

- Performing the discrepancies analysis according to a predefined set of categories

- Produce accountability report for each confrontation occurrences.

Analysing discrepancies between two estimates is more complex than simply comparing two global cost figures.

There is first the necessity first to ensure that our cost estimate is fair prior to perform any comparison with external sources. Because the two sets of cost figures may have been produced at different times, things may have changed in the meantime:

- Cost models may have been updated, thus recognising some under or over estimates on specific cost items;

- The latest reference scope may have evolved compared to the hypothesis of our past estimate.
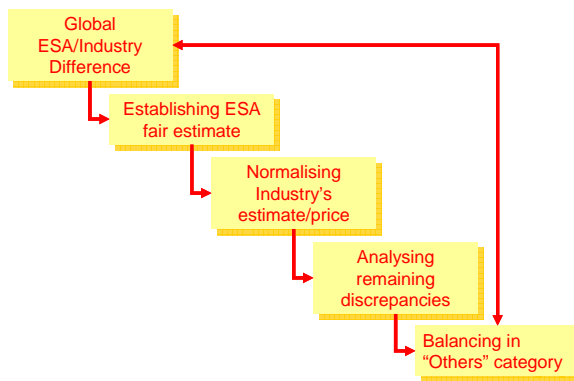
Then one may ensure that the other cost estimate is built on the proper reference scope of work; this may require some normalisation.

Finally one will compare the inner reasons for discrepancies when all these normalisations have been performed.

This sequential process is depicted in the Figure 4 here below:

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Figure 4 – The sequential process for comparing estimates

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To be noticed the last step in this sequence, consisting of balancing the global difference with the aggregation of the 3 previous steps. This comes from the fact that the discrepancies categories are not fully independent one from another, so second-degree differences when applicable are not caught and need to be balanced into the "Others" category.

The following discrepancies categories have been considered split per process step:

- Establishing ESA Fair estimate
  - o ESA model underestimating

- o ESA model overestimating
  - o ESA under scope
  - o ESA over scope

- Normalising Industry's estimate

  - o Industry under scope
  - o Industry over scope

- Analysing remain discrepancies

  - o Heritage /TRL difference
  - o HW Matrix/Development Plan differences
  - o Procurement approach differences
  - o Cost Risk coverage differences
  - o Industry under pricing
  - o Industry over pricing

- Balancing global discrepancies within "Others" category.

The results are displayed in a web chart as per Figure 5 here below.
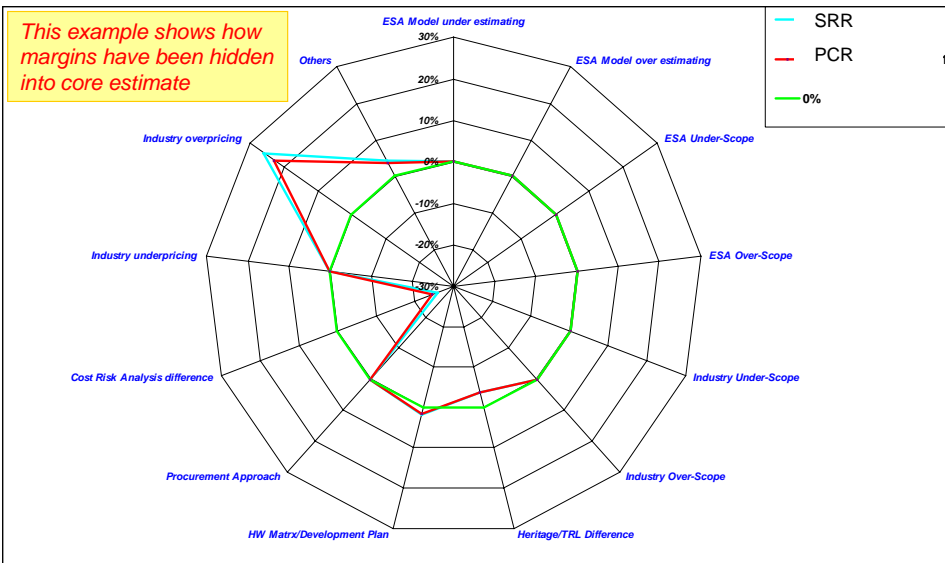
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Figure 5 – Typical discrepancies analysis web chart

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These web charts can be used for analysing the evolution of the estimates at different times of the project life but can also be aggregated by domain like "Science" or "Earth Observation" and allow detecting specific trends for each of these domains along time.

Ultimately, the accountability data is not only reinsuring the project stakeholders that our estimates are fair and, if not, that discrepancies are identified and treated. It also provides an excellent and extremely powerful market follow-up tool to support Industrial Policy and control the long term trends in cost estimates evolutions.

7. Conclusions

This paper has shown that providing cost estimating services at the right professional standard level is not limited to building and using nice CERs, but also requires developing proper methods and procedures to enrich and pacify the relation with the different stakeholders. The goal is to provide them with useful tools that effectively contribute to the overall management of the procurement activities. These are the conditions for the cost engineering entity to be considered credible and useful and so become robust and long-lasting.

8. References :

1. *AACE International recommended Practice No 17R-97*
to learn more on classes of estimates

2. *http://evm.nasa.gov*
to learn more about EVM

3. *http://emits.esa.int/emits-doc/ECOS/ecosmain.htm*
to get ECOS details, software and resources

4. *Improving transparency into the Cost Risk Assessment process*
   (H. Joumier, S. Abitzsch ISPA 2006 Annual Conference Seattle)
to know how contributors' shares of the cost risk provision are calculated