Analysis of external and internal risks in project early phase

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Abstract

During the early “conceptual” phase of a project life-cycle – considering for instance a competitive bidding process when a request for bidding has been received by an engineering & contracting company and the decision to bid has been made – the main objective of the proposal manager is to achieve an effective trade-off between the bid competitive value on the side of the client expectations and the project baseline in terms of time/cost/performance constraints on the side of the utilisation of the internal resources. Since project final performance depends primarily on risk analysis and management, a “risk driven approach” to Project Management appears to be necessary, particularly during the project early phase when only scarce information is available and contractual obligations are to be taken. In this context, both “internal” risk (e.g. probability of cost overrun) and “external” risk (e.g. probability of winning) must be taken into account.

The paper presents the PRIMA (Project RIsk Management - IST-1999-10193) research project aiming at implementing such a “risk driven approach” to Project Management through the development of a Risk Management Corporate Memory and a Decision Support System allowing for collecting, storing, sharing, using company knowledge both in terms of data records and experts knowledge in order to improve the company capability of project risk analysis and management.
1. Introduction

The most critical phase in the project life cycle is the conceptual phase or bidding process, since only scarce information is available and nevertheless the project baseline has to be determined, baseline that more or less becomes a constraint for the project in terms of time and cost and product performance. In other words, the proposal manager faces an obvious, but not easy to loose, trade-off: the more competitive the bid in terms of offered price and non-price factors, the greater may be the probability of winning, but, conversely, the higher may be the probability of deviation from the planned project baseline.

Three main problems should be addressed:

- How to estimate the bid competitive value and measure the probability of winning?
- How to estimate the project baseline and measure the probability of meeting the related constraints?
- How to integrate both estimates, trading off bid competitive value and project baseline constraints with the related uncertainty levels?

1.1 Knowledge structuring

The competitive value of a bid is estimated using competitive factors (such as price, delivery time, technical assistance, process safety, training service, plant dependability, etc.), which have to be defined, following a top-down approach. Since these factors may be either qualitative or quantitative it is necessary to use, together with the limited set of factors available, a suitable ranking model. The ranking is related to the influence of each competitive factor on the overall bid competitive value. Obviously, the point of view of the owner is quite different from the contractor’s one (in the latter case all the data should be estimated through educated guess).

Competitive factors may be structured in different ways, depending on the availability of external information (client, competitor, market) and the possibility to identify the cognitive process of experts on the domain:

- as a simple list
- as a hierarchical structure and a taxonomy of factors
- as a semantic network
- as a database or knowledge base
- etc.

A global performance indicator for the bid competitive value is calculated using the competitive factors as parametric variables. The calculation algorithm depends on the number of parameters, the type of ranking or the knowledge structure complexity. This problem may be effectively approached by a Multi Attribute Decision Making model, such as, for instance, Saaty’s Analytic Hierarchy Process, which is in fact a prioritisation technique.

On the other side, when estimating the overall project baseline, a breakdown approach may be applied choosing an appropriate level of detail, taking into account that the more detailed the analysis the greater the amount of information required. Baseline factors may be structured in such a way to make possible a detailed knowledge capitalisation and an appropriate working method to build technical solutions, using information stemming from previous projects. A traditional way to estimate a project baseline is based on an analytical approach. It requires a breaking down of the project in terms of products, processes, resources and related costs. The overall project cost is therefore estimated summarising up all the detailed cost items. A quicker way to project baseline estimate – more suitable for the bid/no bid early phase during the bid process - may use a parametric approach based on the identification of the main cost, time and performance drivers and the use of rates and adjustment factors corresponding to the specific case considered.

Specific models are generally required in order to evaluate overall project main performance parameters: cost (e.g. Cost Breakdown Structure) duration (e.g. Project Network) and product performance (e.g. Value and Functional Analysis).

Obviously, maintaining a memory of the information concerning previous projects, considering both bid competitive value and project baseline, makes more efficient and effective the process of proposal preparation, since an intelligent reuse of recurrent information items can be organised. Such information can be qualitative and quantitative and should consider product/service performance, client evaluation criteria, competitors behaviour, project context, etc.

The main information sources for the “bid competitive value” and “project baseline” estimate are data records and experts knowledge. Information sources may be internal or external to the company involved in the competitive bidding process.
1.2 Knowledge processing

Classically, the bid process focuses on cost estimations as a final point of the technical solutions building process and a comparison with the possible price is made (DECIDE, ESPRIT n.22298). As previously mentioned, the early phase of the project is characterised by a high level of uncertainty, affecting both competitive factors and cost/time/performance parameters. But risk is “the” prime management factor.

In this context, a “risk driven approach” to project management appears to be necessary, since project final performance depends primarily on project risk analysis and management along the overall project life-cycle. As a consequence, project risk analysis and management tends more and more to become an essential requirement for project management quality.

From the contractor point of view a competitive bidding process poses two kinds of relevant decisions:

- the problem of bidding (bid/no bid decision), i.e. the choice whether to take part in the auction or not, which primarily depends on a preliminary evaluation of the contractor strengths and weaknesses and must be viewed in the light of a project portfolio strategy and some assumptions about competitors behaviour;
- the bidding problem, i.e. the choice of the bid profile, pursuing the objective of winning the competition without overbidding.

During the bidding phase the contractor has to decide whether to accept an external risk (described by the probability of winning) on the basis of the presumable judgement given by the client on his bid compared to those prepared by competitors, simultaneously incurring an internal risk (described by the probability of deviation from the project baseline representing a constraint for the project).

Such a decision can be supported by the above mentioned knowledge organisation. But a new way to define and take into account risk should be applied at project management level.

The concept of risk is normally associated to an adverse event and described in terms of probability of occurrence and severity of consequences. But for managers, risk is as well threat and opportunity, which could affect adversely/ favourably the achievement of project objectives.

Risk sources may be considered classically, as internal sources (i.e. related to industrial risk subject to company control), against external sources (i.e. related to market risk not subject to company control). For example, current company overall workload causing a possible slippage in project completion date, against currency fluctuation causing a possible financial loss.

The knowledge process organisation needs an identification of risks as soon as possible during the proposal preparation process. For each project, it is possible to identify a list of “risk sources” from which a set of “risk events” may stem: for instance an increase in the purchase price for an equipment item may stem from current market conditions and a loss of competitive value of the bid may stem by local safety rules and standards which have not been correctly considered.

2.PRIMA proposal preparation process

A PRIMA model of the proposal preparation process has been developed in order to point out the main decision steps where risk aspects should be taken into account.

Normally, the first step of the proposal preparation process is the preliminary analysis of the Request for Proposal, leading to a bid/ no bid decision. In the case of bid decision a corresponding bid strategy should be determined. The second step should include the start- up and planning of the proposal preparation process.

The actual development of the technical solution suitable for the client’s requirements and the corresponding cost estimate involves different contributions coming from each functional department, contributions to be integrated by the proposal team. In PRIMA (IST-1999-10193), the analysis of internal and external risk is developed during the bidding process. Each alternative technical solution, corresponding to a bid profile and a project baseline, should be evaluated in terms of internal and external risk (Exhibit 1). An iterative adjustment process may be requested in order to obtain an effective trade-off between internal and external risk. At each iteration possible risk mitigation actions can be considered - modifying bid profile and project baseline - or further information can be requested. In both cases the degree of confidence on the value and cost of the bid should be estimated as a result of the risk analysis. The process ends with the final approval and the close-out step, in which memory about learnt lessons should be gathered.

As a follow-up step, data about each bid should be collected and maintained in a Risk Management Company Memory (RMCM): the project actual values should be recorded and compared to baseline expected values in terms of time, cost and product performance for each successful bid; in any case, estimated deviations of the bid profile from other competitors’ bid profile, particularly form the winner’s in case of unsuccessful bid, should be analysed and recorded.
Exhibit 1. Proposal preparation process

2.1 Principles of the PRIMA project

As a consequence of the above considerations about the proposal preparation process, objectives of the PRIMA project is to define, develop and disseminate a «Management by Risk» method and the associated software tools: a Risk Management Corporate Memory and a Decision Support System for bidding.

The PRIMA method and toolkit organises:
- risk knowledge capture, storage and reuse during the early phase - e.g. bidding process - of programs, projects, products or services life cycle;
- a risk referential with a precise definition of internal risk (affecting products, processes, resources, costs) and external risk (stemming from clients, customer(s), market, competitors, strategic position, regulation, environment, …), structured for business decision-making;
- projects and enterprise performance estimators.

The RMCM is designed to be:
- knowledge-constructive, as it supports adjustment to new cases when reusing knowledge, ontology restructuring and cases addition, either from the bid process itself or from other sources;
- knowledge-emergent, as it allows tacit knowledge capture from senior proposal managers, learning from experience for young employees and supports best practices.

The Decision Support System (DSS):
- supports bid construction. Bids can be arranged through the provided analytical organisation of products and processes, allowing with better precision and quickness blue-prints, sketches, bid/no bid decisions, essays and simulation, risk drivers estimation and work distribution and refinement;
- provides bid pricing and evaluation by risk, with internal and external risk analysis;
- helps organise co-operative work during the process of bid construction. The Risk Breakdown Structure is the basis for a GroupWare as it provides a co-operative language used by the proposal team to acquire, share, make coherent and value distributed knowledge about risks.

The research project starts with a review of as-is methods and practices. Benchmarking techniques are used. Information is gathered through interview techniques and used to support the initial expression of needs. In parallel a research overview is performed in order to determine the state of the art of scientific developments and new research areas in the field of DSS and knowledge capture. The conceptual modelling will then be adapted to the bidding phase. The results of these tasks are then combined to define the global system architecture making the best use of functional analysis results and existing tools, modules and methods available within the PRIMA consortium.

The toolkit production makes use of prototyping methods. The detailed specifications and architecture of the software tools are established and the generation of module specifications is shared among the PRIMA partners. After being tested the modules will be integrated and the complete tool will be validated. During the last part of the development phase the users representatives will undertake an evaluation phase, to examine the capability of the product to satisfy the customer needs. The initial needs expression will be reviewed and improvements implemented. The documentation (User's guide, Tutorial) will be updated and released.

The experimentation phase follows, to evaluate the efficiency of the approach. This phase is prepared in the early months of the project in parallel with the global architecture definition by identifying the type of test schemes and input data, the data base organisation and the performance indicators. Once the tool is eventually available, simulations will allow for evaluating the overall system performance.

Dissemination will be conducted along the project life cycle together with the preparation of the exploitation plan. It starts with a marketing study, the customisation strategy in each country is defined and industrial associations are kept informed. Once the product is available, methodology is disseminated by means of publications, workshops, Internet sites etc. and the tools are disseminated towards industry (especially small and medium sized companies) through the industrial partners.

The composition of the consortium in charge of the PRIMA research project includes important research and industrial partners, specifically: ALCATEL Space Industries, UT1 (Université Toulouse1, Department Sciences Sociales Pour l’Ingénieur), CR2A-DI (software house specialised in the use of IC technologies for scientific and technical applications), AICIA (Andalusan Association for Research and Industrial Cooperation), SAINCO (Sociedad Anónima de Instalaciones de Control), NTUA (National Technical University of Athens, Division of Mechanical Design and Control Systems and Industrial Management & Operations Research Sector), Hellenic...
2.1.1 External risk

Assuming that the decision to take part in the auction has already been taken, the bidding strategy, i.e. defining the bid profile in terms of technical, financial, service-related and contractual aspects can be driven by different objectives. For instance, a period of crisis due to a work underload could force the contractor to submit a bid in order to maximise the probability of winning ($P_{\text{WIN}}$) even if the resulting profitability could be low or even negative. When a significant work load is available, on the other hand, the objective could be maximising the monetary value which is expected in submitting the bid. The latter is widely assessed as the expected profit contribution (EPC), i.e. the product of the probability of winning ($P_{\text{WIN}}$) and the profit contribution if the bid is won, which is equal to the difference between the price offered and the expected cost, ($P - C$):

$$\text{EPC} = P_{\text{WIN}} \cdot (P - C).$$

The bid profile in terms of technical, financial, service-related and contractual aspects determines both the project baseline and the competitive value of the bid (Exhibit 2), which may be evaluated considering both the owner set of evaluation criteria and the competitors bids profile. The contractor faces an obvious trade-off: the more competitive the bid in terms of price and non-price factors, the greater may be the probability of winning, but, conversely, the lower may be the profit contribution because of price reductions and/or cost increases. The bidding problem is generally a question of choosing the bid profile which maximises the expected profit contribution. However, in order to enter a new market or when there is a work under-load the contractor could accept a lower EPC trading off a lower profit contribution with a greater probability of winning.

Exhibit 2. Decision framework in the bid preparation process

Since competitive bidding is a one-of-a-kind process, the proposal manager has to face with the uncertainty concerning his judgements, due to imprecise and vague knowledge of the competing context and the project baseline as well. The degree of uncertainty is generally high at the beginning of the bid preparation process and reduces as new pieces of information become available.

Both the problem of accurate project baseline estimate and quantitative evaluation of bid competitive value are well recognised as fundamental issues in the bid preparation process (Kotler 1987, Churchman 1957, King 1990, Ward 1988). This section focuses on the latter issue, since fewer results are available especially in decision contexts in which multiple, quantitative and qualitative factors have to be considered.

The assessment of the bid competitive value is characterised by at least two relevant sources of uncertainty:

- the appraisal scheme of the owner, i.e. owner evaluation criteria and their relative importance;
- the profile of competitors bids.

Assuming the point of view of the owner, the bid appraisal is in general a multi-criteria decision problem where both economical and technical elements must be considered. In fact, due to the complexity of the offered “product”, bids may conform differently to the specific requirements and be non-homogeneous in their technical, financial, service-related and contractual aspects. Moreover, the growing level of competition together with increased customer expectations have broadened the number of service and financial aspects which are used to differentiate competing bids. In addition, competitive bidding is usually a group decision making process in which different points of view should synthesise in a common decision.

It becomes necessary to develop a model allowing the contractor to estimate the bid competitive value on the basis of the information currently available concerning the owner, the competitors and the profile of his own bid.

Models so far developed to assess the probability of winning are mainly based on the assumption that the competitive value of the bid primarily depends on the price offered. Various methods of calculating $P_{\text{WIN}}$ as a function of the price offered have been suggested (King 1990, Friedman 1956, Vickrey 1961, Gates 1967, Rothkopf 1991, McAfee 1987). In most cases, the computation of $P_{\text{WIN}}$ is a hard task due to the necessity on one hand to consider the relationships of dependence among the competitive value of competing bids and on the other to refer to historical data on competitors past performances. These difficulties have the effect of reducing the user confidence in the results of the above mentioned techniques. Moreover, taking decisions based just upon price is getting less and less important and the only way to design useful decisional support tools is to take into account non-price competitive factors as well.
The importance of non-price factors is well recognised in the literature (Ward 1988, Simmonds 1968, King 1985 & 1988, Seydel 1990). Exhibit 3 provides a tentative overview of the main competitive factors describing the profile of a bid concerning the engineering & contracting sector. Even though some papers also suggest to correct P_{WIN} with non-price elements (Ward 1988, Simmonds 1968, King 1985 & 1988) little work has been done on this issue and no analytical means is provided to implement these suggestions.

Exhibit 3. Relevant factors in process plant design and construction

A model for the evaluation of the bid competitive value should present the following characteristics:

- multi-attribute structure, allowing the integration of quantitative and qualitative factors in the assessment of the bid competitive value;
- allowance for uncertainty in individual judgements;
- integration in a rigorous way of the information becoming available during the decision making process;
- support to group decision making;
- flexibility, i.e. easy adaptability to decisional contexts which may be extremely different and characterised by one of a kind conditions.
- robustness, i.e. reduction of possible uncertainty effects of the overall estimate

Multi-Attribute Decision Making techniques in general, and Analytic Hierarchy Process in particular, appear to be suitable for competitive bidding problem, particularly using a probabilistic version based on Monte Carlo simulation. This way not only a rank order of the competing bids may be obtained but also an evaluation of the probability of winning.

2.1.2 Internal risk

In the case of internal risk, the first problem to be addressed is which element of the project is affected by a given risk driver. In order to carry out a systematic analysis a Work Breakdown Structure (WBS) is requested, considering for instance deliverables, functional systems, components, integration make and buy processes, resources and costs (Exhibit 4).

Exhibit 4. Work Breakdown Structure

At this point a very critical decision deals with the detail level of the risk analysis: the more detailed the breakdown of the project the higher the amount of information to be collected and maintained. As a second problem, it is necessary to identify the links between risk sources (identified by the Risk Breakdown Structure) and project elements (identified by the Work Breakdown Structure), in order to estimate the major effects of a given risk source on different project elements (obviously effects stemming from the same risk source are correlated). In this context risk events correspond, for each project element, to possible deviations of actual values from expected values in terms of cost, time and product performance (Exhibit 5).

Risk Breakdown Structure allows for an identification of the major risk types: policy, sales, contractual and legal, procurement, management, technical, safety, financial, etc. For instance, "management risk" could be broken down into different sources, such as WBS badly defined, project schedule inconsistent, lack of circulation of useful information, resources inadequate or unavailable, etc. Note that a given risk source (e.g. currency fluctuation) may affect both the internal and external risk parameters (i.e. estimated project budget and price offered).

Exhibit 5. Risk Breakdown Structure and Work Breakdown Structure

Considering the probability of incurring a risk event, the magnitude of the possible deviation allows for a quantification of the risk. Obviously different models of the project are required if different types of risk are to be analysed: a Cost Breakdown Structure model for cost risk, a Network model for time risk, a functional model of the product for performance risk, a cash flow model for financial risk, etc.
3. PRIMA Decision Support System

A DSS is an interactive, flexible and adaptable Computer-Based Information Systems (CBIS) that utilises
decision rules and models coupled with a comprehensive database and the decision maker’s own insights,
leading to specific decisions in solving problems that would not be amenable to management science
optimisation models per se. Thus, a DSS supports complex decision making and increases its effectiveness.
A DSS is composed of the following parts:
• Data Management. It includes the database(s), which contains relevant data and it is managed by software
called Data Base Management Systems (DBMS).
• Model Management. A software package that includes financial, statistical, management science, or other
quantitative models that provides the system’s analytical capabilities and an appropriate software
management.
• Communication. Interface with user.

Exhibit 6. Architecture of PRIMA Decision Support System

The architecture of PRIMA DSS is described in Exhibit 6. The main modules composing the DSS are:
• Estimate module (allowing for cost, time, performance point estimates based on drivers, coefficients and
factors).
• Statistical module (allowing for a measure of the forecasting capability of the company based on data
records and expert judgement).
• Risk Breakdown Structure – RBS - (allowing for an identification and classification of the major risk
sources).
• Work Breakdown Structure (allowing, through cross analysis with RBS and at a given level of detail, the
identification of the major risk events, their probability and consequence in terms of deviations from
expected values of cost, time and product performance).
• Simulation Models (value, cost, time, product models which allow, through simulation, the assessment of
the overall risk in terms of cost, time and product performance using input data coming from Statistical
Module for each risk event).
• Risk Evaluation Module (allowing for a trade off between external risk and internal risk, identifying
possible actions to reduce overall risk level).

The increasing complexity of projects and products leads to the analysis of huge amounts of data. Moreover the
bidding process requires the involvement of different skills and resources in a very short period of time based on
knowledge sharing, both over space and time. A formal process of knowledge acquisition, structuring,
accumulation, sharing, reuse and adaptation to new cases makes it possible a co-operative approach to work and
a learning process at company level.

The PRIMA DSS focuses on trading off “external” risk analysis (i.e. analysis of uncertainty about bid
competitive value following a top-down approach) and “internal risk (i.e. analysis of uncertainty about possible
deviations from project baseline following a bottom-up approach). The trade-off between these two sides of
project risk is normally obtained by an iterative process allowing for a progressive adjustment of the bid profile
taking into account the several aspects involved.

In the case of PRIMA RMCM the main information sources are data records and expert knowledge. The relative
weight of these two types of sources may change: the more non-repetitive is a project element the more
important is the expert judgement during the assessment phase. On the contrary for repetitive elements data
records may exercise a greater influence in the assessment. The integration between available data records –
generally limited by project “one of a kind” features – and subjective judgements elicited by experts on the basis
of previous experience about similar projects is an inherent issue of the knowledge engineering process.

The approach to cope with the quantitative aspect of proposal preparation process is often deterministic since
only “point estimate” values are used for the input parameters of the models applied to estimate both the bid
competitive value and the project baseline respectively (e.g. activities budget and duration). But, as previously
mentioned, the early phase of the project is characterised by a high level of uncertainty, affecting both
competitive factors and cost/time/performance parameters. As a consequence, during the risk quantitative
assessment phase - following the risk identification phase and anticipating the risk response development and
risk response control phases - in order to safeguard contractor’s uncertainty and nevertheless assess the risk
implied in the project, an approach based on “distribution estimate” - and not on “point estimate” – should be applied when estimating parameters related to bid competitive value and project baseline. Distribution estimates can represent both the uncertainty of an individual involved in the decision process and the dispersion of judgements in a group decision making process. 

Such a distribution estimate allows for a greater information content to be used in the early phase of the project and for an answer to new questions – impossible to answer with the traditional deterministic approach - such as: how probable is the success for our bid? How confident are we about the possibility to comply with given constraints in terms of budget and duration? Is it worth carrying out research to reduce uncertainty through gathering further information? 

Only the availability of a Risk Management Corporate Memory allows for an implementation of a distribution estimate approach and, as a consequence, an evaluation of the likelihood of a given budget or completion date estimates. Considering for instance data records, the shift from an “expected value” (point estimate) approach to a “distribution estimate” approach should imply an evaluation of the company forecasting capability. Distributions of forecasting errors – i.e. deviations of actual values about time/cost/performance from the expected values -, stemming from data records and adjusted by experts opinion, may be used to obtain a “distribution estimate” for each relevant project element, considering both competitive factors and project baseline parameters. Since the main information sources are data records and expert knowledge, a distribution estimate should stem from a rigorous integration of both sources, based for instance on a Bayesian approach.

4. Conclusions

The PRIMA method and toolkit represent a modular approach to risk analysis and management during the early phase of a project. The traditional approach based on a “point estimate” of cost and value of the bid, leading to a final trade-off between these two aspects, is enriched by the analysis of the “internal” and “external” risks associated to the technical solution developed during the proposal preparation process, eventually arriving at a trade off between the two aspects of risk. Such a trade-off process allows for a progressive joint adjustment of the bid profile and the project baseline constraints respectively. This objective may be achieved by obtaining further information or implementing suitable risk mitigation policies. The availability of a Risk Management Corporate Memory allowing for gathering, storing and reusing information stemming from previous bids and projects make it possible firstly to estimate and improve the forecasting capability of the company and secondly to estimate and improve the degree of confidence on given target values of the project in terms of cost, time and product performance. The feedback of experience consists in recording the risks, the methods used to deal with them and their effectiveness.

References


