Selecting projects in a portfolio using risk and ranking

Luis Copertari
Computer Engineering Department, Autonomous University of Zacatecas, Mexico

Abstract

There are three dimensions in project management: time, cost and performance. Risk is a characteristic related to the previous dimensions and their relationships. A risk equation is proposed based on the nature of the uncertainty associated to each dimension as well as the relationship between the uncertainties. A ranking equation that is able to prioritise projects is proposed and discussed. The problem solved here is which projects to select in a given portfolio of projects. The model is implemented in a group decision support system (GDSS) which can guide decisionmakers in their decision process. However, the system is not intended as a substitution of the decisionmaker task, but merely as an aid. The methodology used is analysis of the equations proposed and trial and error based on examples. This paper's main contribution is the risk equation and the ranking equation.

Keywords

Portfolio management, risk management, project management, ranking

Introduction

Project management is a managerial approach that integrates complex efforts by restructuring management and adopting special methods such as PERT/CPM, tradeoff analysis and risk management, in order to obtain better control and use of existing resources. Project management fosters cross-functional communication among operational islands across management and function gaps within the organisation (Platge, et al. 1999; Kerzner 2009).

Driven to compete in global markets, organisations face considerable pressure to introduce new products with shorter lifecycles satisfying minimum quality requirements at competitive prices. Business functions are merged in order to reduce the time it takes from

Journal of Project, Program & Portfolio Management Vol 2 No 1 (2011) 10-28

concept to market. Management methodologies such as concurrent engineering, total quality management and just in time manufacturing, among others, have been applied in order to cope with a fast-paced, highly competitive and dynamic global marketplace. In this context, comprehensive planning is a must. Successful project selection and management requires best practice, particularly in the case of knowledge and technology-based organisations in which successful R&D is a key ingredient (Ries & Trout 2000).

According to Meredith and Mantel (2008), the phases required for developing new products or updating existing ones are conceptual (preliminary design), definition (including detailed design), production (including prototype manufacturing), operations and divestment. The traditional management approach to product development is sequential, with periodic revisions and iterations between phases. The concurrent engineering approach is to merge these phases in an ongoing project evaluation and analysis process. Concurrent engineering (Baram 2000; Denker 2001; Hoedemaker 1999; Powell 1999; Terwiesch 1999) reduces time to market by squeezing the product development lifecycle, carrying some of the product development phases and their tasks in parallel. A project consisting of a combination of two or more mutually inclusive tasks with pre-specified precedence relationships can, in fact, be considered a single project.

But what is a project? A project is an organised set of activities of finite duration to be accomplished, having a given purpose or goal (well-defined set of desired end results), with some unique elements and stakeholders (client, parent organisation, project team, and the public). *A project is a combination of interrelated activities that must be executed in a pre-specified sequence in order to complete an entire task* (Meredith & Mantel 2008).

A portfolio is a set of projects to be selected from a given pool, which may be mandatory (they must be executed), mutually exclusive (either one project or the other is selected, but not both) or mutually inclusive (if A precedes B and project B is selected, project A must be selected first, but not necessarily the other way around, that is, project A could be selected without selecting project B). For any given portfolio, there is a planning horizon for the time in which the portfolio is being considered, a budget for the total amount of money available for the selected projects and minimum performance requirements such as a minimum Internal Rate of Return (IRR) or a minimum Net Present Value (NPV). Measuring performance is very hard. IRR is used as the measure of performance because a similar duration of the projects is assumed. If this is not the case, the NPV of each project can be used instead. Even though these are financial measurements, they are used as performance measurements simply because of their convenience for numerical purposes, since performance (or quality) may usually be measured using qualitative indicators instead of quantitative ones.

Time, cost and performance tradeoffs

Successful project management is the supervision of company resources, which involves project completion within the allocated time period, within the budgeted cost and at the proper specification level, resulting in positive benefits such as customer satisfaction among others. Time (indicated as a given schedule), cost (constrained by the budget), and performance (described as quality requirements for given specifications) are the three main project management dimensions (Meredith & Mantel 2008).

Time is outlined as milestones or deadlines in a schedule. Cost is profiled by money allocations in a budget. Both are variables that should be minimised. Specifications are qualitative or quantitative descriptions of the deliverables as portrayed in the Statement of Work (SOW). The SOW is a list of the tasks or deliverables of the project organised as a hierarchy, where the key tasks are subdivided into a series of activities. The SOW allows decisionmakers to identify activity precedence.

These specifications can be of two types: a) specifications to be met, and b) specifications to be exceeded. Quality is a measure of conformance to specifications. For the first type of specification, quality is a function of specification variance: more/less quality implies a lower/higher variation from the specification given. For the second type of specification, quality is a function of the specification itself: more/less quality implies exceeding/lagging behind the specification given. Projects usually have two or more specifications to measure performance. Such specifications are project-specific. The NPV and IRR are considered here to be the measures of performance.

Time (schedule), cost (budget), and performance (quality or technical specifications) are the three project management (PM) prime objectives or targets (see Figure 1). Although the relationships among these dimensions vary from project to project, from time to time, and even within projects, it is possible to portray such dependencies as tradeoffs. Klein (1993) considers the uncertainties associated with each of these dimensions and portrays them as risk tradeoffs. Figure 1 portrays the probabilistic nature of PM dimensions by drawing a probability density function associated to each dimension. The due date is the time at which the project should be completed. The probability of not completing the project on schedule is the time risk. Also, the budget indicates the maximum cost allowed. The probability of having a cost greater than or equal to the budget constitutes the cost risk. Performance is different. Assuming the performance measurement is a type of specification to be exceeded, performance risk is the probability of having a performance less than the performance requirement.

A great deal of good project management involves good project risk management. Project risk management can be defined as *the implications of the existence of significant uncertainty about the level of project achievement* (Chapman & Ward 2003). Tight time, cost or performance targets increase time, cost or performance risks. A risk situation is often regarded as the existence of potentially very high and unacceptable costs or threats due to events assumed to be more or less likely to happen. This negative approach to risk leads to the idea that risk management essentially deals with removing or reducing the possibility of underachievement. Risk analysis is not a ‘throwing a dice’ situation, but rather an area of study in which a proactive, creative and intelligent prior planning approach is used, as opposed to being entrenched in a defensive position (Adams 2001; Dey 2001; McManus 2001; Schimmoller 2001).

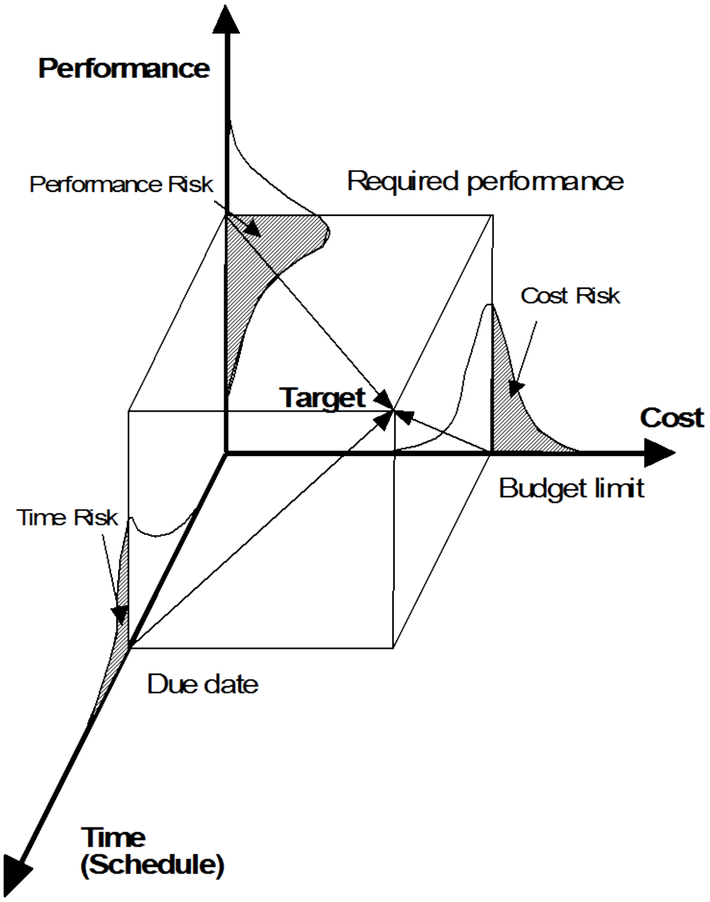


Figure 1. **Time–Cost–Performance Tradeoff Adapted from Meredith & Mantel (2008: 3)**

In this context, it is important to distinguish between risk and uncertainty. Risk is the likelihood or probability of failure, whereas uncertainty is the variability of the relevant outcomes for a given risk or eventuality. Brealey and Myers (2007) define risk as the condition that more things might happen (at present) than will happen (in the future). Uncertainty, on the other hand, is the degree to which an identified threat or risk (at present time after prior assessment) will (presumably, based on experience, historical data or assumptions) vary. Uncertainty is an identified (and quantified) risk. Still, the degree to which such identified risk will vary is unknown. Uncertainty thus constitutes the ‘known unknowns’ because although a specific risk has been identified, its actual impact is still unknown. Non-identified risks are ‘unknown unknowns’ because, generally speaking, a risk is non-quantified uncertainty about something not yet considered to be possible as a future outcome. It is assumed throughout that risk identification has been successfully and thoroughly carried out and will focus on the risk due to the uncertainty for the most relevant variables previously identified by decisionmakers. Risk sources are any factors that can affect the project's dimensions. Setting a tight time target such as an optimistic project deadline increases the project's time risk. Likewise, an unreasonably small budget increases cost risk and setting a minimum NPV increases performance risk. On the other hand, allowing slack times, contingency budget allocations or lowered NPV decreases time, cost or performance risk, respectively (Dawson 1998; Farrell 1996; Lefley 1997; Tavares 1998). Risks do not necessarily give a negative result. A given risk could go either way. For example, consider a given project is going to be paid in dollars, but it is going to have all its costs in pesos. If each dollar costs 10 pesos and the peso then becomes devalued, so that now each dollar costs 14 pesos, for the stakeholders this would be a positive event because they would still receive the same amount of dollars but the dollars would have more value in pesos than before. In this case, the outcome of the currency exchange uncertainty is positive.

Project selection

Project selection is one of the first and most critical activities in PM. Deciding from a pool of available and competing projects which ones should be undertaken (thus assigning limited resources to them) and which ones should not be undertaken or terminated is a complex decision. Overall value maximisation, balance among dimensions, and business strategy should be considered. Portfolio selection is a process characterised by uncertainty and changing information: new opportunities arise, multiple goals as well as strategic considerations are required, and interdependence among projects (either when competing for scarce resources or when synergies are achieved) exist, not to mention multiple decisionmakers and locations. Consequently, a mathematical model built into a flexible group decision support system (GDSS) developed within an optimally designed web-based user interface (WUI) to foster interaction between decisionmakers seems to be the best long-term approach to tackle such a complex decision-making process.

According to Meredith and Mantel (2008), project selection methods can be classified as nonnumeric (qualitative) or numeric (quantitative). The sacred cow, operating necessity, competitive necessity, product line extension and the comparative benefit model are among the qualitative methods. Profitability models[1] and scoring models[2] are among the quantitative methods.

A decision support system for project portfolio selection is presented by Archer and Ghasenzadeh (1998). An alternative zero-one integer programming model, is described by Ghasemzadeh et al. (1999).

There is no such thing as the optimal portfolio when we consider the tradeoffs among time, cost and performance (not to mention risk preferences). Decisionmakers have to weight multiple project dimensions and intuitively decide how adding or removing a specific project would have an impact on the portfolio. In other words, they face intuitive decisions on marginal contribution (gain or loss). Our conjecture is that *the best decision is achieved when overall cost and time are minimised while maximising performance for a given risk profile.*

Let the column vector $\mathbf{x} = [x_1,\ldots,x_s]$ be a set of zero-one integer variables indicating whether or not project k is included into the portfolio, where s indicates portfolio size (total number of projects available): $x_k=1$ indicates project k is selected and $x_k=0$ indicates project k is not selected. Let the row vector $\mathbf{q} = [q_1,\ldots,q_s]$ be the performance estimates of the project portfolio as indicated by their IRR.

Denote the time and cost dimensions of the projects using the row vectors $\mathbf{t} = [t_1,\ldots,t_s]$ and $\mathbf{c} = [c_1,\ldots,c_s]$, where t_k and c_k, are the completion time and total cost of project k. Also, let $\mathbf{r} = [r_1,\ldots,r_s]$ be the risk vector, where $0 \le r_k \le 1$ is the risk of project k given as a fraction. Denote the absolute variability associated with the time, cost, and performance dimensions using vectors $\mathbf{\Delta t} = [\Delta t_1,\ldots, \Delta t_s]$, $\mathbf{\Delta c} = [\Delta c_1,\ldots, \Delta c_s]$, and $\mathbf{\Delta q} = [\Delta q_1,\ldots, \Delta q_s]$, where Δt_k, Δc_k, and Δq_k are the absolute deviation of the time, cost, and performance estimates of project k so that $t_k-\Delta t_k \le t_k \le t_k+\Delta t_k$, $c_k-\Delta c_k \le c_k \le c_k+\Delta c_k$, and $q_k-\Delta q_k \le q_k \le q_k+\Delta q_k$. These are assumed

---

[1] Payback period, average rate of return, NPV, IRR, profitability index, as well as others that subdivide the elements of the cash flow, include terms of risk or uncertainty or consider the effect on other projects or the organization.

[2] Weighted and non-weighted zero-one factor models, with or without constraints, usually solved using integer programming as well as goal programming when multiple objectives are given.

to be symmetrical about their mean values. Risk preference is the risk level (in percentage points between 0% and 100%) at which decision-makers are comfortable. The solution vector is denoted as the column vector **x*** = [x_1*,…,x_s*] where x_k* is the "optimal" solution for project k indicating whether or not such project should be included in the portfolio. The relative importance of time, cost, and performance are indicated using weight factors denoted as w_t, w_c, and w_q, respectively, where $w_t+w_c+w_q=1$.

Now consider a small example of three projects: Alpha, Beta and Gamma, as shown in Figure 2. The weights for each dimension are: $w_t = 0.35$, $w_c = 0.40$, and $w_q = 0.25$, so that their sum is 1. The budget for the portfolio is $4,500.

Project	**Time in weeks (t_k)**	**Time uncertainty (Δt_k)**	**Cost in dollars (c_k)**	**Cost uncertainty (Δc_k)**	**Performance in percentage (q_k)**	**Performance uncertainty (Δq_k)**
Alpha	7	4	2,000	500	8%	2%
Beta	3	3	1,500	1,000	7%	3%
Gamma	10	4	2,500	500	5%	4%

Figure 2. Small illustrative example

Risk profile

Calculating the portfolio's risk profile is particularly cumbersome. In any case, how can we measure risk? Although risk and uncertainty are not the same, uncertainty can be used as a measure of risk. (We assume risk to be the 'known unknown as discussed earlier.) Consider our example and the uncertainties for time, cost and quality. The performance for project 1 can be as high as 8+2=10% or as low as 8-2=6%. The cost can be as high as $2000+$500=$2500, if particularly unfavorable events arise, or as low as $2000-$500=$1500 in a favorable situation. If project 1 ends up being as costly as possible ($2500) while achieving its lowest performance (6%), would it be selected as part of the optimal portfolio? Even if project 1 costs $2500 rather than $2000, the budget limit should not be exceeded ($2500+$1500=$4000 ≤ $4500). So, again, it is a question of marginal contribution. Each performance point now would cost $2500/6 = $416.67, which is still less than the marginal contribution for project 3 ($500). But if project 3 performs particularly well (5+4=9%) while at the same time being particularly cost-effective ($2500-

500=\$2000), then its marginal contribution would be \$2000/9 = \$222.22. The latter would change the optimal solution, from **x*** = [1,1,0] to **x*** = [0,1,1].

How likely is the above scenario? In other words, how risky is project 1? It seems that the risk of project 1 depends on how much uncertainty for time, cost and performance exists for project 1 as well as the combined uncertainty of projects 2 and 3. This requires some form of weighting among dimensions. For example, how much more important is time when compared to cost or performance? The Analytic Hierarchy Process (AHP), developed by Saaty (1977) can be used to assign relative weights based on a series of pairwise comparisons. Continuing our example, assume that this weighting has been determined to be $w_t = 0.35$, $w_c = 0.40$, and $w_q = 0.25$. A measure of relative uncertainty is the uncertainty to average ratio (g_k, k=1,…,s). Each project has three such ratios for time, cost and performance. The uncertainty to average ratio for time is the uncertainty associated with time divided by the time estimate itself $\Delta t_k/t_k$. The same applies to cost and performance: $\Delta c_k/c_k$ and $\Delta q_k/q_k$. The overall uncertainty to average ratio for project k is the weighted average, $g_k = w_t(\Delta t_k/t_k) + w_c(\Delta c_k/c_k) + w_q(\Delta q_k/q_k)\ \forall\ k = 1,\ldots,s$. In our example, $g_1 = 0.3625$, $g_2 = 0.7238$, and $g_3 = 0.4200$. But, as we have seen, the risk for project 1 is not only a function of the uncertainty associated with project 1, but a function of the overall uncertainty associated with all the projects. In short, the risk for project k, $r_k = (g_k/(\Sigma g_j))\text{x}100\%$, j=1,…,s, and $0 \le r_k \le 1$. Thus, $r_1 = g_1/(g_1+g_2+g_3) = 24.07\%$, $r_2 = g_2/(g_1+g_2+g_3) = 48.05\%$, and $r_3 = g_3/(g_1+g_2+g_3) = 27.88\%$. The uncertainty variations are given in equation (1).

$$g_k = w_t \frac{\Delta t_k}{t_k} + w_c \frac{\Delta c_k}{c_k} + w_q \frac{\Delta q_k}{q_k}, \ k = 1,\ldots,s \tag{1}$$

The value for the risk estimate is calculated in equation (2) based on the uncertainty estimations from equation (1).

$$r_k = \frac{g_k}{\sum_{j=1}^{s} g_j}, \; k = 1,\ldots,s \qquad (2)$$

The ranking equation

Generally speaking, we can say that good projects consistently have relatively high performance and relatively low time and cost figures. Consider our example. The best (lowest) time is for project 2, followed by project 1 and finally project 3. The best (lowest) cost is for project 2, followed by project 1 and finally project 3. The best performance (highest figure) is for project 1, closely followed by project 2 and with project 3 coming last. It seems the best project to select is project 2 (2 out of 3 best figures), followed by project 1 (1 out of 3). Project 3 is certainly not a wise choice. What have we just done? We have selected a set of projects for the portfolio. Among these selected projects we can now formalise a priority index and use it to generate a list sorted by rank in order to classify projects as high priority, medium priority and low priority. This will help decisionmakers to make further allocations among projects in the portfolio.

The priority index summarises all the estimates and their relative priority when compared with the portfolio (set of available projects). Let Z_k be the classification index for project k, where $0 \le Z_k \le 1 \; \forall \; k=1,\ldots,s$. A project is considered to be low priority if $0 \le Z_k \le {}^1/_3$, medium priority if ${}^1/_3 < Z_k \le {}^2/_3$, and high priority if ${}^2/_3 < Z_k \le 1$. This scheme implicitly assumes that the higher the index, the better the project. The classification index must include the three project management dimensions. The weights for time, cost and performance (w_t, w_c, and w_q) can be used to embody the three dimensions into one single number. But the units for time, cost and performance are not equivalent (we have time units such as years, months or weeks, money units such as thousands, millions or billions of dollars, and performance units in percentage). So, first, we have to transform these figures into ratios. Let t_{Min} and t_{Max} be the minimum and maximum time estimates ($t_{Min} = Min\{t_k\}$and $t_{Max} = Max\{t_k\} \; \forall \; k=1,\ldots,s$), c_{Min} and c_{Max} be the minimum and maximum cost estimates ($c_{Min} = Min\{c_k\}$ and $c_{Max} = Max\{c_k\} \; \forall \; k=1,\ldots,s$), and q_{Max} and q_{Min} be the maximum and minimum performance estimate ($q_{Max} = Max\{q_k\}$ and $q_{Min} = Min\{q_k\} \; \forall \; k=1,\ldots,s$).

Let rt_k and rc_k be the time and cost ratios for project k, k = 1,…,s. The classification index sorts projects from the highest to the lowest ratio. So we need to invert the time and cost figures, assigning the lowest figure to the highest estimate and vice versa. In order to do that, we have to subtract from the maximum value of all the estimates the given estimate for each project (t_{Max}-t_k and c_{Max}-c_k). The best estimate is always going to be t_{Max}-t_{Min}. Thus, $rt_k = (t_{Max}-t_k)/(t_{Max}-t_{Min})$. A similar reasoning can be applied to cost: $rc_k = (c_{Max}-c_k)/(c_{Max}-c_{Min})$. The reasoning for performance is different, because there is no need to invert the value. We can take the performance estimate and simply subtract the minimum performance and divide that by the performance range, so that $rq_k = (q_k-q_{Min})/(q_{Max}-q_{Min})$. The overall index is the weighted average of these ratios, $Z_k = w_t rt_k+w_c rc_k+w_q rq_k$, k=1,…,s as indicated in equation (3).

$$Z_k = w_t \frac{\mathrm{Max}\{t_j\} - t_k}{\mathrm{Max}\{t_j\} - \mathrm{Min}\{t_j\}} + w_c \frac{\mathrm{Max}\{c_j\} - c_k}{\mathrm{Max}\{c_j\} - \mathrm{Min}\{c_j\}} + w_q \frac{q_k - \mathrm{Min}\{q_j\}}{\mathrm{Max}\{q_j\} - \mathrm{Min}\{q_j\}},$$

$$j = 1,\dots,s,\ k = 1,\dots,s \tag{3}$$

In our example, $Z_1 = 0.6$[3], $Z_2 = 0.9167$[4], and $Z_3 = 0.0$[5]. This means that project 2 has higher priority than project 1 which, in turn, has a higher priority than project 3. In short, $x_2>x_1>x_3$. Actually, project 2 is a high priority project ($^2/_3<0.92\leq1$), project 1 is a medium priority project ($^1/_3<0.60\leq{}^2/_3$), and project 3 is a low priority project ($0\leq0.0\leq{}^1/_3$). This means that, in principle, decisionmakers should select project 2 first, then (if possible) select project 1 and finally select project 3 if all constraints are satisfied. But this is not necessarily the best decision because equation (3) does not consider the risk profile. For example, project 2 scores the highest, but at the same time is the riskiest. Although project 1 does not score as high, its risk is the lowest. Our aim is to help decisionmakers to quickly realise which projects should be definitely left out by interacting with data and choices through a GDSS. The information in the example for the risk and ranking estimates for each project are summarised in Figure 3.

---

[3] Z_1 = 0.35(10-7)/(10-3)+0.40(2500-2000)/(2500-1500)+0.25(8-5)/(8-5) = 0.6

[4] Z_2 = 0.35(10-3)/(10-3)+0.40(2500-1500)/(2500-1500)+0.25(7-5)/(8-5) = 0.9167

[5] Z_3 = 0.35(10-10)/(10-3)+0.40(2500-2500)/(2500-1500)+0.25(5-5)/(8-5) = 0.0

Project (k)	**r_k**	**Z_k**
Alpha (k=1)	24.07%	0.60
Beta (k=2)	48.05%	0.9167
Gamma (k=3)	27.88%	0.0

Figure 3. Risk and ranking estimates for the illustrative small example

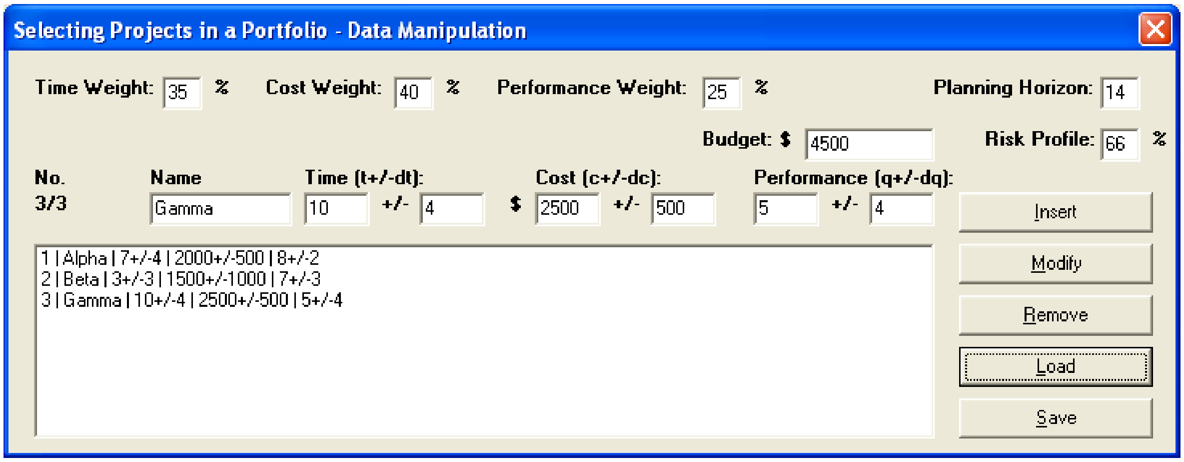
The Group Decision Support System (GDSS)

Based on all of the theory discussed above, a Group Decision Support System (GDSS) was built using Delphi (Pascal). The system allows users to enter the projects and their time, cost and performance specifications including their respective uncertainties and plots the results using a bubble chart. The ranking equation is used to determine the color of the bubble (red for low priority projects, yellow for medium-priority projects and green for high-priority projects[6]).

The application has two windows. The first window allows users to plot the data. Using this window, it is possible to open another window in which the data to be plotted can be entered and manipulated, saved to file or loaded from file. The interface for such a window applied to our example is shown in Figure 4.

---

[6] Notice here the use of these colours so that the ranking is immediately clear. However, if colours cannot be used for printing, it is possible to use silver instead of green, medgray instead of yellow and gray instead of red. Nevertheless, it is hard to notice the difference in shades in this case, so sticking with green, yellow and red seems a better idea.


Selecting Projects in a Portfolio - Data Manipulation

Time Weight: 35 % Cost Weight: 40 % Performance Weight: 25 % Planning Horizon: 14

Budget: $ 4500 Risk Profile: 66 %

No. 3/3 Name: Gamma Time (t+/-dt): 10 +/- 4 Cost (c+/-dc): $ 2500 +/- 500 Performance (q+/-dq): 5 +/- 4

1 | Alpha | 7+/-4 | 2000+/-500 | 8+/-2
2 | Beta | 3+/-3 | 1500+/-1000 | 7+/-3
3 | Gamma | 10+/-4 | 2500+/-500 | 5+/-4

Figure 4. Data manipulation interface for the GDSS

The data entered in Figure 4 is shown in Figure 2. After entering the values shown in this figure, saving them (or loading them after saving them[7]) and closing the window, another window appears. This is the main window, which has two main buttons: ‘Plot Data’ and ‘Data Manipulation’. If the Data Manipulation button is clicked, the window in Figure 4 appears. Once the data shown in Figure 4 has been entered and the main window is shown, it makes sense to click on ‘Plot Data’, since now there are data to be plotted. The result is shown in Figure 5.

Notice that there are three combo boxes. The first combo box is along the X axis and is labelled “Cost”. The second combo box is along the Y axis and is labelled “Performance”. Finally, the third combo box is at the top right of the figure and is labelled “Time”. These are the three dimensions for a project. Each of these combo boxes contains three options: “Time”, “Cost” and “Performance”. If they are changed, what is plotted also changes. In this case, cost is plotted along the X axis, performance is plotted along the Y axis and time is plotted along the “Z” axis. But what is the Z axis in this two-dimensional graphic? The Z axis is the vertical length of the bubbles along the Y axis. Although the units along the Z axis are not the same, performance is plotted in percentage points and the distance of the bubbles, which represents Z, is plotted in weeks in this case.

---

[7] Refer to File1.spr.

Figure 5. Main interface for the GDSS

To interpret the graphic, it is necessary to see it and analyse it. First of all, notice the three different colours. Project Beta is green, project Alpha is yellow and project Gamma is red. These colours come from the calculation of Z_k from equation (3), the ranking equation. This means that choosing project Gamma is not a wise choice. Generally speaking, the further to the right a project is, the more it costs and the less likely it is to be included it in the portfolio.

But what about the Y axis? This axis provides the more important and subtle information. The higher (more towards the top of the chart) a project is, the higher its performance. Thus it seems that project Alpha has the highest performance (8%), closely followed by project Beta (7%) and, finally, project Gamma (5%). So once again, it is not a wise choice to select project Gamma.

The chart also includes the calculation of the risk value associated to each project based on the uncertainties compared to the actual figures of each project when compared to the others. Alpha has the lowest risk (24.07%), closely followed by Gamma (27.88%) and finally by Beta (48.05%). Now the choice is not so clear. Although project Alpha (which is marked yellow, meaning reasonably good) has the lowest risk, project Beta (which is marked green, meaning good ranking) has the higher risk. It is up to the decisionmakers to decide what is more important: ranking or risk when it comes to project Gamma.

What about the other uncertainties? It is possible to create a chart in which all dimensions are cost. It is also possible to create a chart in which all dimensions are time or performance. This gives an idea of how high in cost, time or performance each project is. However, in the end, the decisionmaker has to decide what is most important: the values of the dimensions themselves, which is what the ranking equation represents; or the variability within these dimensions, which is what the risk figure given represents.

Larger example

Figure 6 shows the entry data of a larger example[8]. This is used to illustrate the limitations of the model. When there are too many projects such that they obstruct each other, the interface becomes useless. Also, when the uncertainties for time are relatively large compared to the time estimates, and the time estimates are considerably large compared to the performance estimates, the bubbles will tend to align along a relatively horizontal line, making performance visualisation difficult.

---

[8] Refer to File3.spr.

Project	**Time in months (t_k)**	**Time uncertainty (Δt_k)**	**Cost in million of dollars (c_k)**	**Cost uncertainty (Δc_k)**	**Performance in percentage (q_k)**	**Performance uncertainty (Δq_k)**
Leo	5	1	240	10	20%	2%
Libra	3	1	2040	200	10%	1%
Virgo	3	1	450	40	30%	3%
Orion	2	1	1400	300	15%	2%
Sagittarius	2	1	40	20	20%	2%
Hydra	3	1	1950	300	50%	3%
Perseus	3	1	300	35	60%	4%
Pyxis	3	1	66	20	45%	5%
Sextans	7	1	1600	320	35%	4%
Aquarius	12	2	2480	420	5%	2%
Taurus	3	1	550	35	10%	5%
Andromeda	2	1	144	30	12%	6%
Centaurs	3	1	750	40	16%	8%
Phoenix	3	1	10	5	6%	3%
Antlia	4	2	650	45	4%	1%
Draco	4	1	165	40	8%	4%
Cassiopeia	3	1	850	65	10%	4%
Lynx	3	2	1000	60	55%	7%
Scorpio	2	1	188	50	50%	6%
Gemini	2	1	90	30	65%	10%

Figure 6. Entry data for a larger example

The previous example results in the plot shown in Figure 7. Notice now that the best projects are located in the top left corner of the chart. This is because the best projects are going to be the ones with the larger performance and the lowest cost, as well as a reasonable time estimate. Also notice from Figure 6 that the lowest time estimate is 2+/-1, and the highest time estimate is 12+/-2.

There is no considerable difference between the time estimates (they are all given in months), so that the use of the IRR instead of the NPV is allowed. The one project that is marked red is Aquarius, so the system recommends not undertaking it. Given the fact that there are many projects, and several (11 out of 20) that are marked green, it seems reasonable to undertake the green projects and leave out the yellow ones and the red one (unless the decisionmakers also consider risk as important). However, in this case, the risk figures are pretty much even (having Leo with the lowest risk, 2.1%, and Sagittarius with the highest risk, 7.58%). Nevertheless, projects such as Andromeda may be left out for not having such a high performance (12%) and a relatively high risk (7.22%) and some other projects, marked yellow, considered instead.

Figure 7. Bubble plot for a larger example

Discussion and conclusion

A good GDSS should allow users to interact with it. In this case, the projects should initially appear blank, and become coloured only when the user selects them. Also, mandatory projects, mutually inclusive and mutually exclusive projects should also be considered in the interface. For example, it should not be possible to unclick a mandatory project, nor include a project without its predecessor, nor have two mutually exclusive projects selected at the same time. Also, as projects are selected, the figures for the budget, planning horizon and risk estimates should be displayed on the screen.

Ultimately, the portfolio is a tradeoff decision between priority and individual risk preferences. In our first example, project 2 would be the preferred choice for high-risk investors while project 1 would be the best choice for low-risk investors. Given the fact that decisions are going to be taken by a group of people, there is no such thing as an optimal solution, and some form of consensus or at least compromise will be required.

The risk equation (2) is a very valuable tool. The values for the risk equation are shown next to the names of each project in the interface. However, the interface could be extended and implemented using a web-based design to allow different decisionmakers in different locations to interact with it and the mathematical formulas built-in.

As shown in the second (larger and more realistic example), when there are several projects in the portfolio, the bubbles may overlap. This almost does not happen here,[9] but in other examples it could happen. If this is the case, a good idea for analysing the problem would be to plot each dimension (Time, Cost and Performance) in all three axes (X, Y and Z). This is the basic limitation of the interface. It may overlap the bubbles, but such limitation may be solved by using the strategy proposed here.

References

Adams, C. 2001, Risk aversion, *Project Finance*, vol. 1, no. 1, 2-5.

Archer, N. & Ghasemzadeh, F. 1998, A decision support system for project portfolio selection, *International Journal of Technology Management*, vol. 16, no. 1, 105-114.

Archer, N. & Ghasemzadeh, F. 1999, An integrated framework for project portfolio selection, *International Journal of Project Management*, vol. 17, no. 4, 207-216.

Baram, G. 2000, Concurrent delays –what are they and how to deal with them?, *AACE International Transactions*, vol. 1, no. 1, R7A-R14A.

Brealey, R. & Myers, S. 2007, *Principles of Corporate Finance*. McGraw Hill, New York.

Chapman, C. & Ward, S. 2003, *Project Risk Management: Processes, Techniques and Insights*, John Wiley & Sons, New York.

Dawson, R. 1998, Practical proposals for managing uncertainty and risk in project planning, *International Journal of Project Management*, vol. 16, no. 5, 299-310.

Denker, S. 2001, Planning concurrency and managing iteration in projects, *Project Management Journal*, vol. 32, no. 3, 31-38.

Dey, P. 2001, Project time risk analysis through simulation, *Cost Engineering*, vol. 43, no. 7, 24-32.Farrell, L. 1996, The impact of illiquidity and uncertainty of the multiperiod project investment decision process, *Project Management Journal*, vol. 27, no. 3, 35-45.

---

[9] Although you can see that Andromeda and Draco are close together, and the names and risk estimate of Sagittarius and Leo mix a little.

Ghasemzadeh, F., et al. 1999, A zero-one model for project portfolio selection and scheduling, *Journal of the Operational Research Society*, vol. 50, 745-755.

Hoedemaker, G. 1999, Limits to currency, *Decision Sciences*, vol. 30, no. 1, 1-18.

Kerzner, H. 2009, *Project Management: A Systems Approach to Planning, Scheduling and Controlling*, John Wiley & Sons, New Jersey.

Klein, J. 1993, Modeling Risk Trade-Off, *Journal of the Operational Research Society*, vol. 44, no. 5, 445-460.

Lefley, F. 1997, Approaches to risk and uncertainty in the appraisal of new technology capital projects, *International Journal of Production Economics*, vol. 53, no. 1, 21-43.

McManus, J. 2001, Risk in software projects, *Management Services*, vol. 45, no. 10, 6-10.

Meredith, J. & Mantel, S. 2008, *Project Management: A Managerial Approach*. John Wiley & Sons, New York.

Platge, A., et al. 1994, Project and Portfolio Planning Cycle, *International Journal of Project Management*, vol. 12, no. 2, 100-106.

Powell, A. 1999, Strategies for lifecycle concurrency and iteration — a system dynamics approach, *The Journal of Systems and Software*, vol. 46, no. 2, 151-161.

Ries, A. & Trout, J. 2000, Focus in a fuzzy world, *Executive Excellence*, vol. 17, no. 14, 3-4.

Saaty, T. 1977, A scaling method for priorities in hierarchical structures, *Journal of Mathematical Psychology*, vol. 15, 234-281.

Schimmoller, B. 2001, The shifting sands of risk management, *Power Engineering*, vol. 105, no. 9, 3.

Tavares, L. 1998, On the optimal management of project risk, *European Journal of Operational Research*, vol. 107, no. 2, 451-469.

Terwiesch, C. 1999, Measuring the effectiveness of overlapping development activities, *Management Science*, vol. 45, no. 4, 455-465.

About the author:

Dr Luis Copertari is a professor and researcher at the Autonomous University of Zacetcas, México. He is an Industrial and Systems Engineer graduated from the Monterrey Institute of Technology and Advanced Studies (ITESM), graduated with honors. He also has a Master in Administration majored in Finance also from ITESM. He holds a Ph.D. in Management Science and Information Systems from McMaster University (Canada). During his Ph.D. he took a course on "Principles and Practice of University Teaching", which proved most valuable for his teaching duties. He has been a member of the American Association for the Advancement of Science (AAAS) from 1998 to 2001 and in 2005. His major research interests are Project Management, Operations Research, Information Systems and Artificial Intelligence.

Email: copertari@yahoo.com