The Successive Principle
– a scientific crystal ball for management

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Abstract—*The management tool known as the Successive Principle*[1] *is an example of successful interdisciplinary R&D involving management, Cost Engineering*, Systems Economy*, statistical theory and some psychology.*

Existing methods of project cost estimating, planning and business analyses too often lead to overruns, delays, etc. when used as the basis for decision-making.

The solution discussed in this paper has achieved a strongly enhanced realism in terms of its estimating procedures, and has largely eliminated unplanned overruns, delays, etc.

The paper outlines the basic principles behind this solution as well as some examples of experiences and applications.

In conclusion, management and other decision makers can now restrict overruns etc. to cases of severe force majeure events.

Index Terms— *Interdisciplinary Research, MBA & Systems Economy, Project & Risk Management, Statistical Theory, Group Psychology, Budget Overruns & Delays*.

1. INTRODUCTION

This publication exemplifies successful interdisciplinary research and development work. It exemplifies the synergic value of integrating different scientific areas. The result is a multi-purpose management tool called the Successive Principle.

Like glasses which give the short-sighted driver a sharper long-distance view, this tool gives the management user a sharper and more realistic long-distance view of the future. A realistic quantitative result of large, complex ventures can now be predicted with substantially augmented realism.

Users have even called it a scientific crystal ball. Furthermore, it identifies in ranked order the most interesting factors of the venture in question.

Revised manuscript received Nov. 20., 2005. This work was supported in part by the Norwegian National Science Fund, and Danish university funding, which are greatly appreciated.

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Its primary professional areas of application are Management & Project Management, Systems Engineering, Risk Analysis & Cost Engineering. It is also of interest in R & D work, when a realistic, non-biased quantitative result is required from an input which includes uncertain, fuzzy elements.

2. THE CURRENT PROBLEM

Severe overruns in cost and time frequently bedevil large programmes, projects, strategic ventures etc., both private and public. These cases sometimes are disasters [1].

The Sydney Opera House, the Channel Tunnel and some of the Olympic Games are the most well known but are only the tip of the iceberg.

The Sydney Opera House

Several research projects have shown that among large IT projects only a small minority came out on budget, while the average overrun was considerable [2].

Recent research by Professor B. Flyvbjerg into large infrastructure projects has shown a similar result [3].

This always causes severe problems. Where do we find supplementary funding? Might we end up with an unfinished shell, or at best with a substandard facility? Do we go bankrupt or at of the company's future activities? Cost engineers, planners and other professionals do complex, extensive and skilled work preparing a detailed basis for budget and schedules, so why do we suffer these problems?

The Channel Tunnel

Olympic Games

[1] An * refers to a list of terms.

3. THE BASIC REASON SEEMS TO BE THE OLD NEWTONIAN SCIENTIFIC PARADIGM

A 300-year old paradigm requires us to focus upon matters that can be documented, and to avoid congestion and other subjective and fuzzy matters. It is still a firm basis in the higher education of engineers and economists. This is of course valuable in many cases; however, it can be disadvantageous in some circumstances.

Working with plans for large projects and other ventures, the planners and estimators have to work with incomplete project material, specifications, etc. when preparing the basis for a budget. The cost of the documented material is carefully detailed and skilfully calculated on the basis of historical data and other experience. In addition, they tend to assume that implementation will be relatively controlled, and unhampered by major problems. Finally, they apply a traditional dispensation whereby a somewhat arbitrary 10% is added for contingencies without any documentation.

4. THIS INEVITABLY CAUSES OVERRUNS

A still larger part of the project is not documented even at the point when the crucial decisions have to be taken. Add to this that a conventional budget estimate takes no relevant account of factors such as future added facilities, complications, requirements, unforeseen influence exerted by authorities, the owner, the users, local NGOs, nature's caprices, human failures, etc., etc.: all typically – but not always – representing much larger amounts than the 10% contingency figure. No wonder we often experience large overruns.

Another consideration is that the many parties who have a stake in getting the project approved/authorised naturally wholeheartedly accept the aforementioned conventional and wholly "legal" budgets.

5. RISK ANALYSIS PROCEDURES AS A SOLUTION

Various risk analysis procedures has been developed attempting to remedy uncontrolled overruns and delays. They all include identification of sources of uncertainty, an evaluation phase, and typically a Monte Carlo calculation of the result, consisting of a mean value and a standard deviation, or the so-called S-curve, linking probability to keep to budget versus budget size. A primary method is the Range Method, developed by Michael W. Curran already around 1970 [4].

The existing methods generally suffer from sufficiently covering identification of sources of uncertainty, from biased quantitative evaluation, and from lack of efficient handling the statistical correlations among various uncertain factors. A huge amount of uncertain factors do also hinder a thorough treatment[2].

These problems, since the early 1970´s has been in focus with a successful result, as further developed below.

6. A NEW GUARANTEE AGAINST UNPLANNED OVERRUNS

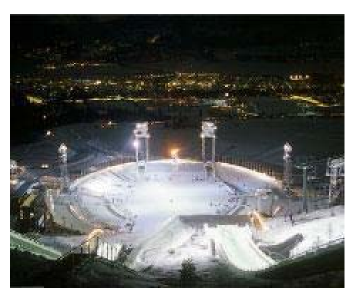
However, a somewhat untraditional procedure has been developed which brings you very close to a guarantee against overruns, except in the case of major catastrophes, obviously. It is known as the Successive Principle*. It was developed during the 1970s and later by the author and colleagues.

One example is the complex high-tech, multipurpose 10,000-seat arena*, Oslo Spectrum* in Norway. The original budget was $45 million. The use of the Successive Principle three years later, before the project was due to start, identified $125 million as a realistic cost. The project was then rationalised, after which an analysis process generated $80 million as a mean value* +/- approx. $10 million as the standard deviation*. The project organisation was allotted the $80 million as a budget, while the official building committee was given the $10 million as a reserve. However this reserve was never used.

The official project account after the successful erection deviated by less than 1% from the calculated mean value.

Oslo Spectrum in Norway

Another example is the *Lillehammer Olympic Games.* The initial budget rose from $230 million to $385 million over the summer, more than four years before the games. A risk analysis showed an expected final total cost of $1230 million. This was of course politically unacceptable. The investment plans were then reorganised –



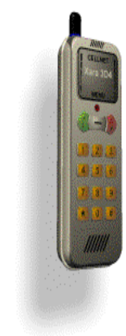
The Lillehammer Olympic Games.

[2] The range method, however have solved this particular problem.

in part supported by the analysis result – and followed by several updating analyses. The expected investment figure was eventually reduced to $800 million as a mean value. This became the working budget, while the official committee was allocated a reserve of approx. $90 million. However, the final official accounts equalled the analysis mean value of $800 million, so the reserve fund was saved and was used to operate the facilities after the games.

The *telecommunications company Ericsson's first mobile or cellular phone* is an example of the use of the Successive Principle as a support for making the right decisions. It was originally allocated relatively low priority among a set of new ideas in an R&D department at Ericsson.

A Successive Principle analysis then revealed it to be a highly promising idea. Accordingly, it was developed and became *Ericsson's* greatest commercial success ever.



Ericsson's first mobile or cellular phone.

It might be said that the above three cases merely capitalised on coincidence or good luck. But over the course of more than 25 years, so far no negative feedback has been received from the sub-set of 250 – 300 cases which were analysed under controlled conditions. But of course not all of the cases ended up quite so close to the exact mean value as the above.

7. DEVELOPMENT OF THE "SCIENTIFIC CRYSTAL BALL"

A. A brief history

This research is based on the new scientific paradigm which accepts and deals with uncertain and fuzzy issues. These ideas was supported by scientists, like Tverski, and Kahneman [5], Spetzler, and Stäel von Holstein [6], Apostoiakis [7], and others.

The aim of the research into the Successive Principle has been to allow professionals to calculate the projected total actual cost or duration of new projects or ventures in a more realistic and controlled manner – more focused on the relevant future uncertainties. It was initiated at the Technical University of Denmark by the author in the beginning of the 1970s [8]. An international research network was formed soon afterwards. It included Stanford University and MIT in U.S.A. as well as universities in Loughborough, UK, Gothenburg, Sweden, and not least the Technical University of Norway in Trondheim [9] - [14]. From the 1980s onwards the practical procedure known as the Successive Principle was in use internationally in most public and private business areas in order to safeguard them against overruns, delays, etc. [15], and [16].

B. The Principle entails the following basic requirements:

- Focus on the future and its uncertainty.
- Inclusion of all internal and external matters that might affect the total result – including fuzzy ones.
- Non-biased subjective evaluation of their impact on the result made by a relevant group.
- Scrupulously following the natural laws of uncertainty during the calculation of the result.

C. The solution tools

- Basic Systems Economy* and Cost Engineering* tools, such as the Net Present Value concept*, Work Breakdown Structures* etc.
- The Bayesian statistical theory* [7].
- The use of group synergy in a balanced and broad-based analysis group of competent people [12].
- A top-down principle involving successive steps detailing the most critical items or factors – and only these – in each step.
- Ensuring sufficient statistical independence* among the uncertain items and factors.
- Using an evaluation procedure which takes the many pitfalls into account.
- A top ten list of the most critical items or factors, updated and used during the successive process and finally used as a key result.

8. THE SUCCESSIVE PRINCIPLE – A PROCESS OUTLINE

The Successive Principle was originally a tool for early and fast cost estimating and scheduling in the construction industry and was known by some users as "intelligent cost estimating". It has developed into an integrated management instrument, as illustrated in section 11, and 12 below, and further developed in a recent handbook [17].

A primary principle is to let a balanced group of key persons perform a few analysis sessions together, during which they identify and then organise all possible sources of uncertainty. They then operate top-down, systematically detailing and evaluating the most important issues in successive steps.

This allows us to keep an overview, to focus on the really important aspects and to avoid wasting resources on the many issues of little or no importance. Another important facet is the arranging of all uncertainties into discrete statistically independent elements and then working with the conditional uncertainty* of each of the elements. This allows simple yet sufficiently accurate statistical calculations.

9. THE PROCEDURE OUTLINED

The procedure is only briefly outlined below due to limitations of space. A more elaborate description and discussion is found in [17].

The procedure is organised into the following eight steps.

Step A. Establish a suitable analysis group.
Step B. Clarify the goals and objectives, as well as any firm preconditions.
Step C. Identify all issues of potential importance.
Step D. Organise the issues into discrete groups, and define for each group a base case assumption and how it could change for better or for worse.
Step E. Quantify all uncertain elements using triple estimates* and good evaluation techniques.
Step F. Calculate a provisional overall result and draw up a top ten list of the most critical items or activities.
Step G. Specify the most critical elements in successive steps, guided by the current top ten list.
Step H. Once a satisfactory result has been arrived at, complete the analysis work with a suggested action plan.

10. IMPORTANT DETAILS

Step A. Establish a suitable analysis group.

An appropriate analysis group is appointed according to the specific purpose of the analysis. In addition to a number of experts representing the major key areas, the analysis group should include individuals who can provide the vital elements of creativity, flair and breadth. The analysis group should ideally include both young and mature individuals, both generalists and specialists and should represent “both halves of the brain". You will usually also need an individual who can play the role of "devil's advocate"; this is especially important in the case of a project whose project team generally wants a successful result, and whose judgement may therefore be over-optimistic.

It is also important to select an appropriate and agreeable location where the analysis group feels comfortable, and in particular will not be disturbed in its day-to-day work; and of course to find rooms where the necessary facilities/ equipment are available and meet professional standards.

The subsequent steps are performed in group sessions, while using modern group psychology inspired by Robert B. Gillis [12].

Step B. Clarify the goals and objectives, as well as any firm preconditions.

The analysis management team will have prepared a draft. However, it is important to discuss it properly in the group and to make adjustments until full understanding and consensus have been reached.

Step C. Identify all issues of potential importance.

The identification of sources of uncertainty (possibilities or risks) is typically achieved by means of a brainstorming process. This usually identifies 50 – 100 issues.

It is specifically verified that the analysis group
has examined a sufficiently broad variety of issues, and e.g. not only the technical ones.

Step D. Organise the many issues.

The identified key words are grouped together into 8-12 statistically independent groups. A clear and simple base case assumption is defined for each group, as well as how it could change for better or for worse. The normal volume of this description is four to seven pages.

Step E. Quantify, using triple estimates and good evaluation techniques.*

A master schedule network or a master calculation structure is chosen. Each main activity, main cost item or factor is quantified from the highest level using the triple estimating technique*. In order to avoid evaluation bias, a specific ‘Group Triple Estimating technique’* has been developed by N. Lange [18] and other, much inspired by C.S. Spetzler and Stäel von Holstein [6]. Shortage of space prevents further mention here of the psychology involved [17, section 5.2].

The activities and related main items are evaluated under the relatively firm base case assumptions. This ensures a sufficient degree of statistical independence. For each group of overall influences a correction figure is evaluated, also using the Group Triple Estimating technique*. It may be in absolute units or as a percentage evaluation.

Step F. Calculate the resulting total and a top ten list of the most critical items or activities.

Statistical independence* is thus largely achieved. To reduce any remaining dependencies further, the analysis group operates with the concept of conditional uncertainties*. This allows a simple yet sufficiently accurate statistical calculation to be made.

The result of the above evaluations is calculated. The calculation follows the natural laws of uncertainty, in this case the Bayesian statistical theory*. In addition to the total mean value* and its uncertainty, a top ten list emerges, showing the most important and critical local sources of uncertainty.

Step G. Specify the most critical elements.

This preliminary estimate or schedule is now detailed in successive steps, with the most critical elements being specified at every step. The guidance in this "intelligent" detailing process is provided by the aforementioned top ten list. It actually leads to an optimal breakdown and evaluation of only those elements which warrant the attention.

Step H. After the final result has been achieved, the analysis work is completed with an action plan.

After a number of such cycles, the elements with inevitable uncertainty will increasingly dominate: after 8 - 12 cycles they usually account for 80 to 90% of the total uncertainty. Consequently, we are close to the minimum uncertainty of the grand total and similarly close to a successful conclusion of the analysis. At this stage, the degree of detailing usually involves fewer than a hundred items of which a considerable number are correction items.

The analysis group will usually be prompted by the top ten list to draw up a suggested action plan by way of a conclusion to the entire analysis process. The aim is to identify actions which may either exploit opportunities, protect the task against risks, or simply reduce uncertainty. A brainstorming process at this point is a highly appropriate means of identifying such ideas.

11. ON EXPERIENCES AND RESULTS

Experiments have verified the psychology behind the subjective evaluations and the use of the Group Triple Estimate procedure [17, section 5.2], and [18]. The statistical calculation procedure has been verified already during the 1970s and 1980s by professors I. Thygesen and P. Thyregod [19].

Practical experiences are primarily drawn from the 250-300 full-scale tasks performed during the last 25 years where it is verified that the procedure has followed "the rules of the game". They cover most business areas and all sizes up to the "mega" size.

The primary result is a most realistic mean value of the actual future total result, whether in terms of cost, time, profitability, resource or consumption. This result is given in statistical mode, with a mean value* and a standard deviation*, or alternatively as the so-called S-curve, indicating the probability vs. the total value.

The top ten list of the resulting most uncertain aspects is also much appreciated by users. Improved team-building amongst the parties involved is also highly appreciated as an important side-effect.

A full statistical breakdown unfortunately is hindered by confidentiality. An exemption is meeting the deadline of large projects [20]. However no negative response has been met so far, only frequent surprise to see a small deviation between the prognosis and the final result. Users frequently implement the Successive principle after having tried it. Even the Norwegian Ministry of Finance has been inspired by the positive results of using the Successive principle to require for all major National projects to use an uncertainty analysis at the front end [21].

12. PRINCIPAL FIELDS OF APPLICATION

The Successive Principle is an integrated approach for:

* Quality assurance of budgets, schedules, profitability analyses and other financial analyses.
* Risk and opportunity analyses.
* Suggested action plans for improvements.
* Ranking of alternative solutions.
* Team building and consensus support.

Sorted by area, it is used as follows.

A. Senior Management, Quality and Risk Management

- Practical elimination of unpleasant surprises (e.g., overruns or delays).
- Risk-assessed corporate budgeting & planning.
- Greater certainties that key issues are being identified and actioned.
- Support for corporate contingency and risk management.
- Loss-making projects may be cancelled in due time.

B. Sales and Marketing

- Sales budgeting and planning
- Consideration of opportunities as well as risks
- in competitive situations
- Bid preparation and development. User companies have proved more frequently to be successful in competitions.

C. Project Management

- Project start-ups are significantly improved.
- Development of realistic plans and budgets.
- Reductions of costs or project duration during project implementation.
- Creative problem solving is supported.
- Team building is supported.

13. SOME LIMITATIONS

Only the overall result is reliable, not each sub-item or activity. Catastrophes and other major 'either-or' or force majeure events require supplementary procedures. The approach is limited to organisations with a modern, open management policy and acceptance of group work.

It supplements rather than replaces planning. It requires trained facilitators who know the "rules of the game". Subjective uncertainty must be accepted. The implementation process requires effort and the support of senior management.

Finally, it must be admitted that the untraditional nature of the Successive Principle often hinders its proper use in more conservative environments.

14. SUMMARY

The Successive Principle is cited in this paper as an example of the benefit of interdisciplinary research. It has used newer scientific paradigms which accept that fuzzy issues must be seriously dealt with. The end result is an integrated management and decision support methodology. It relates well to contemporary post-industrial management principles and attitudes. The strengths and benefits of the approach include

- Enhanced grasp of an uncertain future.
- Consideration and handling of the turbulence and uncertainty of business in a systematic and scientifically sound way.
- Integration of objective and subjective aspects.
- Identification of and focus on the most important uncertainties (risks and opportunities).

ACKNOWLEDGEMENTS

The author gratefully acknowledges the decade-long cooperation with fellow researchers as well as with Futura International, the international network of consultants dedicated to the use of the Successive Principle [15].

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LIST OF TERMS

Bayesian statistical theory is a widely accepted theory, which includes subjective probability in opposition to the classic or frequentistic statistical theory, which only accepts sets of documented data. Both theories use the same set of formulas [7].

Conditional uncertainty is the uncertainty of a local uncertain variable on condition that all other uncertain parameters are in their mean value.

Correlation or dependence coefficient. A statistical concept denoting the degree to which two separate uncertain figures follow each other. One limit is full statistical independence.

Cost Engineering is a part of Engineering Economy or Systems Economy, which deals with the cost of major assignments and related issues, see Systems Economy.

Engineering Economy, see Systems Economy.

Group Triple Estimate procedure is a procedure aimed at obtaining a neutral result by avoiding a set of pitfalls linked to subjective evaluations [17, section 5.2],. See also Triple Estimate.

IPMA, the International Project Management Association, a European and Asian-based professional organisation. See also PMI.

Mean value (also called expected value or expectation value) is a central value of an uncertain figure.

Net Present Value, NPV, is a widely used profitability criterion. It summarises all in and outgoing payments in discounted form (discounted back to the present time) for a specific system in contrast to other alternative ventures.

PMI, Project Management Institute, an American based professional organisation. See also IPMA.

Project Economy, see Systems Economy.

Standard deviation is a statistical measure of the dispersion or variation of numerical data from the mean value (see this term).

Statistical or stochastic independence, see Correlation coefficient

Successive Principle (also called the Lichtenberg method) is a multi-purpose management and Cost Engineering tool used to identify a realistic future result of a venture (cost, duration, profitability etc.) and the related primary uncertain issues.

Systems Economy (also called Engineering or Project Economy) is a part of economic science which deals with the profitability and other economic effects of specific ventures. See also Net Present Value and Cost Engineering.

Triple Estimate. The mean value* and standard deviation* of an uncertain figure is calculated as a weighted sum of the extreme minimum, the extreme maximum (theoretically the 1%, resp. 99% quantiles), and the most likely values. See also the Group Triple Estimate procedure.

Work Breakdown Structure, WBS, is a Cost Engineering concept. It denotes the way in which various sections or sub-systems of an assignment or project are sub-divided into main items, items, and sub-items, in a hierarchical structure for planning or estimating purposes.

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