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The Logic and Insight of Contingency in Projects Budget and Timetable

presented by

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About the IFA Technical Committee

The IFA Technical Committee encourages the development and adoption of technology improvements that can lead to greater production efficiencies and reduced emissions, as well as better health and safety standards throughout the fertilizer industry. Our mission is to actively promote the sustainable development of efficient and responsible production, storage and transportation of all plant nutrients. The Technical Committee accomplishes these objectives through a variety of channels, including:

- Technical and policy-oriented information materials. The committee regularly conducts surveys and produces reports on key industry metrics, including the IFA Energy Efficiency and CO_2 Emissions Report, the IFA Safety Report, and the IFA Emissions Report. This work enables member companies to assess their operations over time, make comparisons with similar facilities on an established level of performance, determine the need for technology improvements and identify good industrial and management practices.
- Regular exchange of information on technology developments and industrial practices. A key role of the IFA Technical Committee is to encourage ongoing technical innovation in the fertilizer industry through the development, compilation and exchange of technical information between members, researchers, engineers, equipment suppliers and other industry associations. To this end, the committee organizes a Technical Symposium every other year to examine progress in the production technology of fertilizers. Each Symposium traditionally features the presentation of 30-40 new technical papers from member companies worldwide, providing members with information on the latest technological developments. In the intervening years, the committee holds a variety of meetings to assess current industrial practices and standards, with an eye toward identifying key developments of interest to members.
- Technical and educational workshops and special events. The IFA Technical Committee provides workshops designed for engineers working in the fertilizer industry, particularly those who have recently assumed new responsibilities, and for new engineers to increase their technical knowledge. These workshops (e.g. concentrating on nitrogen and/or phosphate fertilizer production) are designed to improve the participants' skills and broaden their vision and understanding of the entire industry, including technology, economics, energy use, safety and environmental stewardship. Workshops also provide engineers with an opportunity to exchange ideas, solve specific problems and improve plant operations and profitability.
- Education and advocacy. The IFA Technical Committee recognizes that customers, markets and regulatory environments are best served by clear and concise information on the fertilizer industry and its practices and products. Because the knowledge and expertise found within the fertilizer industry is the best source for this information, the Technical Committee endeavours to educate policymakers, standardization bodies, customers and the public on industry achievements, technological advances, voluntary initiatives and best practices. The committee also encourages universities and development centres to conduct research on fertilizer product development and production processes.

(as provided by the author for distribution in Vilnius)

The Logic and Insight of Contingency in Projects Budget and Timetable

Abstract

- Budgets and timetables are future events: an attempt to estimate/forecast at what cost and date, a project/investment will be completed.
- Future events contain inherent uncertainty: any project, may have several possible final outcomes, which can differ from the original forecast with regard to investment costs and completion dates. In other words, we are dealing with a statistical/probability process.

Remark: from here onward, we shall address investment forecasts, but the same arguments apply to the timetable also.

In order to forecast the outcome with a reasonable and acceptable degree of accuracy, we need data relating to similar events and activities in the past, to which margins = contingency ("safety factors") should be added, the margins estimation, should also be based on past data and information.

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All papers and presentations prepared for the IFA Technical Symposium in Vilnius will be compiled on a cd-rom to be released in June 2006.

The Logic and Insight of Contingency in Projects Budget and Timetable

About Dead Sea Works Ltd.

Dead Sea Works Ltd (DSW), an ICL (Israel Chemicals) subsidiary, is a potash producer with production capacity of 3.8 million t/y, produced from the Dead Sea brines, and with sales all over the world.

DSW was established in 1952, and since then has gained extensive experience in implementing projects, with total cumulative investments of over $1.5 billion.

DSW also owns two European potash producers – Iber Potash in Spain and Cleveland Potash in England.

DSW total yearly production capacity (including its subsidiaries) is 5.7 million tons.

1. Project budget and timetable forecasts

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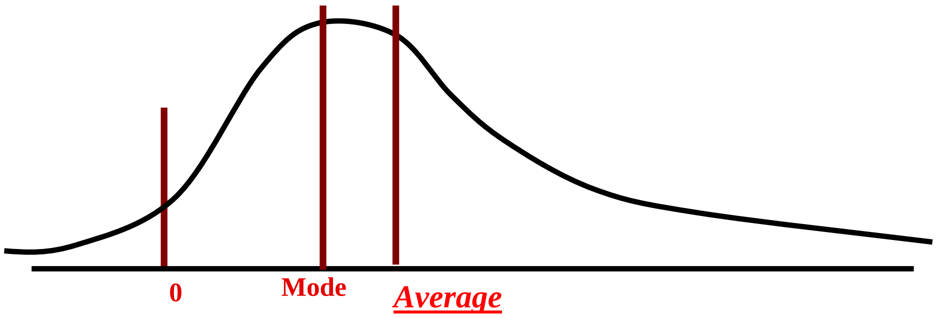
1.1. What can be learned from the analysis of past experience?

Statistical analysis of project outcomes shows that, investment in any specific activity follows a “Gamma” distribution. This distribution is skewed to the right: values higher than the Mode have greater probability.

The estimated value = the investment amount, is the Mode of the distribution.

2. Gamma distribution



Since the lower limit of the distribution is greater than zero [not (-) infinity: investments cannot be neither negative nor zero], the probability for values higher than the original investment estimate (= the Mode) becomes even greater.

2.1. The distribution of the sum of all the project activities

- Since a project comprises hundreds – very often thousands of independent events/activities, we have to relate to the distribution of the **sum** of all these events/activities;
- According to the Central Limit Theorem, the sums of large enough numbers of distributions follow Normal Distribution. Consequently, the investments in projects having large numbers of events/activities will distribute normally (again, the lowest value > zero);
- When estimating investments of projects, in other words, the sum of those of many events and activities, the estimated value we get is the **Mode** of the total investment amount, (which, in the normal distribution, equals the Mean (average) of the distributed values);
- From this, it follows that the probability of completing a project within the estimated budget (and/or timetable) (= the area under the part of the Normal Distribution curve below the Mode/Mean value), **is less than 50%!**
- Investors are interested in the probability of the estimated investment and project completion time (delayed completion also has a negative financial impact) **not be exceeded**.

No serious investor will approve an investment having a probability higher than 50% of being overrun!

2.2. What is Contingency?

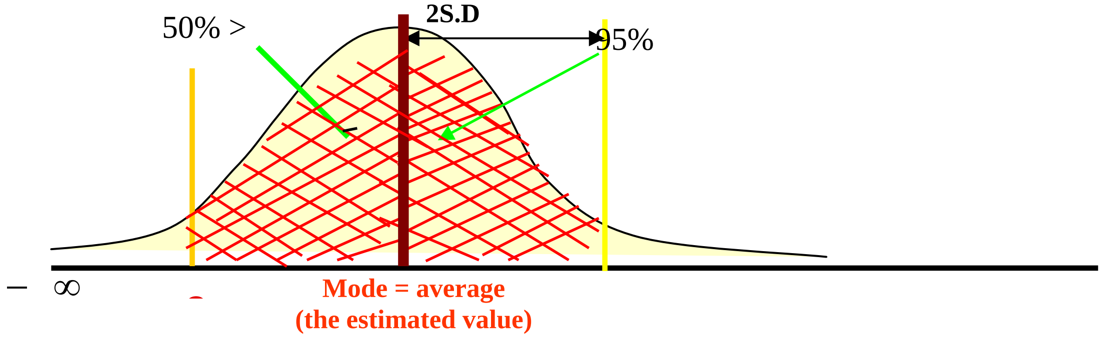
It is common to demand 95% certainty that the budget will not be overrun.

In the Normal Distribution, there is a 95% probability that a value will not exceed the average by more than twice the standard deviation (S.D.).

Thus, it is necessary to estimate also the S.D. of the investment distribution, and adding 2×S.D to the estimated parameter (= the mode), will give the desired budget, i.e., the figure that has 95% certainty of not being exceeded.

2 standard deviations = contingency

3. Normal Distribution



3.1. Level of Accuracy

Most clients and engineering companies, when estimating budgets, use the term: “the desired level of accuracy”, expressed as “accuracy of ± X %” (for example: ± 15%).

It goes without saying, that the probability to complete the project within the estimated budget minus X%, **is significantly lower** than that of completing it within the estimation + X % **!!**

In light of the above, referring to an accuracy level of ± x % **is meaningless!**

The term “contingency level of X%” should be used instead!

3.2. Level of Contingency

The accuracy of the estimation of a budget, is linked to the resources invested in the project evaluation stage = the comprehensiveness and depth of the feasibility study, pre-project, etc.: the greater the investment in the estimation stage, the higher the accuracy, the lower the distribution “width”, the lower the standard deviation and, consequently, the lower the contingency level.

There are several levels of comprehensiveness/depth of budget estimations:

- Lowest level – techno/economic evaluation, pre-project, basic engineering, estimation based on factors;
- Highest level – detailed design, including requests for quotations/tenders, for all activities/equipment, etc.

3.3. Contingency = unforeseen

Contingency is allocated for “unforeseen” expenses.

One may ask, how can one estimate an “unforeseen”.

Reputable engineering companies with vast experience in large projects, have many data and much information that enable comparisons between estimated and final investments and timetables for similar projects performed in the past. From these comparisons, they can estimate the required contingency rate, according to the level of comprehensiveness of the estimation, i.e. the amount of resources invested in the evaluation stage.

Almost the same importance, should be applied to the estimation of the standard deviation: a low estimate will eventually result in budget overrun, whereas too high of an estimate may result in investment rejection.

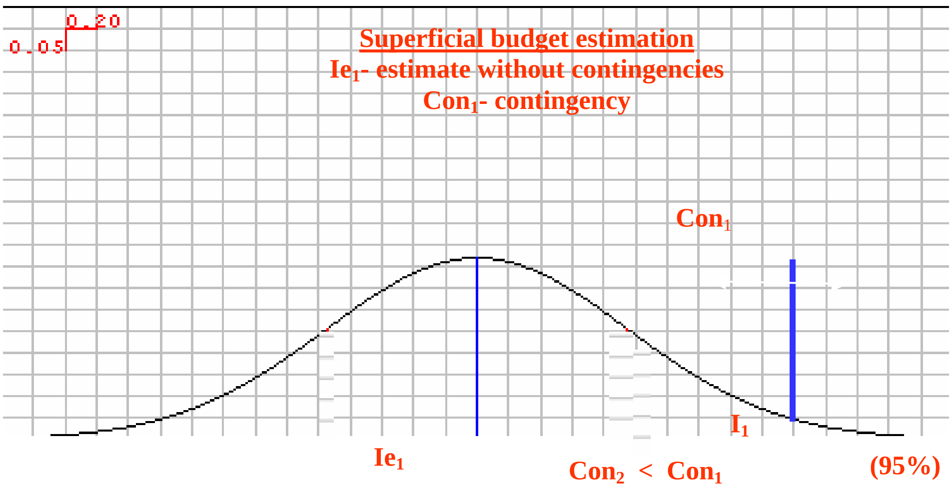
The contingency is usually expressed as a percentage of the estimated total investment. Common values are 10-20% (again, dependent on the comprehensiveness of the estimation).

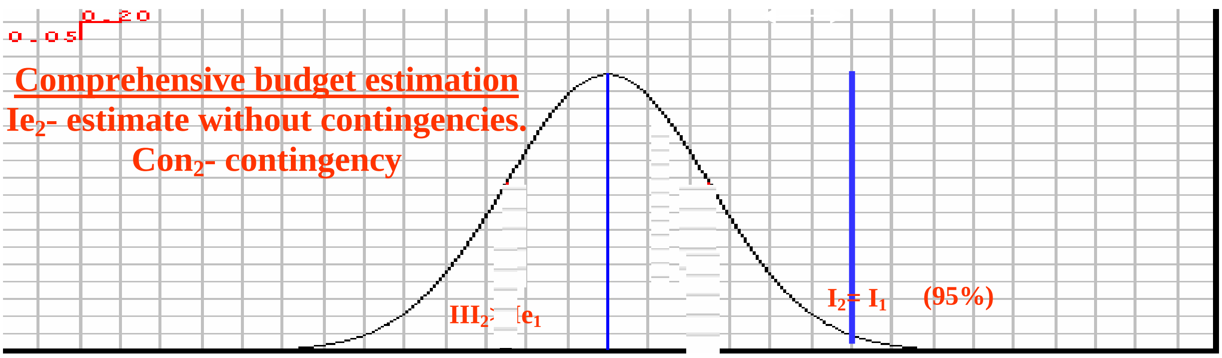
If the investment + contingency are correctly estimated, the project will be completed within the estimated budget, and the contingency allocation will also be expended/consumed. Thus, the estimation of the contingency is no less important than the estimation of the investment itself (the investment Mode/mean).

The significance of the above statement is that, the more comprehensive the estimation, the greater the accuracy of the estimated budget (= estimate without contingency), compared with that of the value obtained from a superficial estimate!

Consequently, the level of contingency required in the case of a more accurate estimation, will be lower, assuming of course that the total final investment is independent of the means invested in the estimation stage (the actual total investment is assumed to be the optimal for the project, i.e., the minimum needed to accomplish the project's purposes and targets).

(a superficial estimation carries a greater probability that various budget items, equipment quantities and prices, and other activities/investments will be "forgotten" or overlooked, than a comprehensive estimation, resulting in a lower, but less accurate estimated investment, necessitating a higher value of contingency to compensate).





3.4. Resources invested in the project estimation stage

The lowest level

Let's take the example of an a new office building. Based on the number of people expected to work in the building and the percentage area allowed/desired for the building in the given lot, we can calculate the number of stories.
From the cost per square meter, according to previous data/experience (if any) with the same type of building (similar soil conditions on which the building is to be build, similar air conditioning and heating requirements, similar numbers of restrooms, elevators, furniture etc.) The total investment can be derived, without any engineering or detailed design.

Needless to say, such estimate will necessitate allocation of higher level of contingency. **However**, if there is sufficient past experience (for example, if similar buildings were built previously and prices of miscellaneous items are known (for example: $850-1150/m^2) the contingency can be estimated correctly, and the final investment will be within the budget + contingency.

The highest level

A comprehensive estimate may include: Investigation drillings for soil evaluation, issuing tenders and requests for quotations for all major activities and purchasing, (furniture, etc.).

Only then, will the total required investment be established. In this case, a contingency still needs to be added, but it will be significantly lower than that in the previous example.

If the two estimates are performed correctly and with expertise, the respective estimates of total (investment + contingency) will be identical or very close to each other.

3.5. Factors affecting contingencies

There are three major uncertainties (unforeseen) that affect the level of contingency required:

- Uncertainties of (unit) prices (differences between actual final prices and estimated ones);
- Uncertainties of quantities (same as for prices);
- Process/technological uncertainties. (Implementing different equipment and/or technologies/process than planned and budgeted at the estimation stage)

The last of these is usually the main cause for large deviations from the original budget estimation.

Example of process/technological uncertainty

1. Solid/liquid separation systems
   The project may involve the purchase and installation of solid/liquid separation systems. There are many types of methods/equipment for solid/liquid separation: thickeners, filters, screens, hydro cyclones, centrifuges, classifiers etc. The basic data (solid particle sizes, settling rates, filtration rates, liquid viscosity, etc.) are not always available at the estimation stage.

At the estimation stage, a specific type of equipment is provisionally chosen and its cost is estimated and budgeted.
Only at a later stage, during the detailed design, the optimum equipment will be chosen, and it might differ from the originally chosen equipment, possibly resulting in (significant) differences in equipment cost from the initial estimation.

2. Equipment for solids transportation
   (Belt conveyors, screw and chain conveyors, elevators, vibrating feeders, pneumatic conveyors, etc.) The choice of the optimal equipment at the advanced stage of the design, may differ (significantly) from the equipment budgeted at the investment estimation stage, resulting in budget over-run.

3. Construction materials
   In the estimation stage, it is not always known which construction materials are the optimal for the application: corrosion and/or erosion/abrasion properties of the materials handled in the process may necessitate (significant) increases in equipment costs at the final design stage.

4. New technology or equipment
   Innovations revealed after the estimation stage may result in a change in the concepts of the process in the detailed engineering stage.
   The two primary types of uncertainties (price/quantity) often offset each other: some unit prices and/or numbers of units may be higher than originally estimated and others lower.

Process/technological uncertainties **almost always** skew towards a higher investment: the probability that various equipment may have been over-looked or not taken into account during the budget estimation stage, is considerably higher than the probability that, during the detailed design stage, some units will be found to be unnecessary, redundant, or that too many units were taken into account.

Design errors **always** cause cost overrun and **never** offset each other.

For example:
The required power of an electric motor/transformer, etc. was calculated, and the device was purchased and installed.

In practice, there are three alternatives:

- The power was correctly calculated. In this case there is no deviation from the cost estimate;
- The calculated power was lower than that required. In this case, a new, motor/transformer is to be purchased and installed. In most cases, there will be no reimbursement for the replaced item, and there will be budget over-run;
- The originally calculated power turned to be higher than required. Namely: the motor/transformer purchased is bigger (and more expensive) than actually required. However, no “discount” is given for this error and this case does not offset the example of the previous case.

Number of units:

- The number of units was properly calculated. No deviation from the budget;
- The number of units calculated, (purchased and installed) is lower than required. The missing units have to be purchased and installed, resulting in budget over-run.

  (The result of this error may be much more severe since the lack of equipment will almost certainly result in a loss of production until the missing equipment is purchased and installed.)

- The number of units calculated (purchased and installed) is higher than that actually required, i.e., it turns out that some of the equipment is redundant.

In this case, there is no deviation, but there is no possibility of returning surplus equipment and getting reimbursement. Consequently, this case does not offset the example of the previous case (shortage of units).

- The case of earthworks (excavations, foundations, construction of dikes, dams, roads, surfaces, etc.), in the ideal case (minimum), the actual quantities will be identical to the calculated (geometry). In practice, the actual quantities will never be lower than the estimated quantities but, on the other hand, there is a high probability that they will be higher, as a result of soil subsidence/collapse, ground water, etc.

  This is another example where the cost is always, skewed to the right and there is no offset of the deviations.

4. Summary

The probability of not exceeding the estimated budget/timetable without contingency is **lower than 50%!**

To increase the level of certainty of completing the project within the budget (and on time) to 95%, the standard deviation has to be estimated and a contingency of 2 × S.D has to be added to the estimate.

When performing an investment estimation, the term "desired accuracy level", expressed as ± X % of the estimation, **is meaningless!**

The term which should be used is the desired contingency rate (% of the inv.).

If the investment and the contingency are estimated correctly, the actual investment for 95% of the projects will not exceed the estimate (including contingency).

An arbitrary deduction or curtail of the contingency from the estimated value (a popular and frequent act by members of the Board of Directors), will reduce the probability of completing the project within the curtailed budget by the same curtailed amount.