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Planning, scheduling and controlling long term projects

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ABSTRACT

The challenge that major projects face is that from design to start-up, the mega infrastructure projects can take up to 10-20 years, maybe even longer. The same applies when we need to control the whole life cycle cost of a project: in research of cost overruns, the general opinion is that these projects are out of control.

Even long term project can be duly kept under control, but we must consider the fact that controlling a short term and a long term project has a different meaning. The paper will show how a long term project can be controlled using dynamics or stochastic methods and taking into consideration that the meaning of controls can vary according to the project characteristics and duration.

Keywords: long term, project, planning, controls, stochastic

DEFINITIONS

This paper is relevant to long term project: we are speaking about major infrastructural projects as well as industrial project, however we shall make some references also to other, longer term projects.

Reference can be made to the study performed by the IMEC (International Program in the Management of Engineering and Construction), based on a sample of 62 projects whose average cost was 985 billion US$, the sample was composed by 15 hydro electrical projects, 17 power plants (thermoelectric or nuclear), 6 urban transportation projects, 10 road projects including bridges and tunnels, 4 petrochemical plants.

Between the findings of the study, it resulted an average duration of 71 months for strategic phase and 49 months for executing the project, so totalling an average duration of 120 months, this is to say 10 years.

Even long term project can be duly kept under control, but we must consider the fact that controlling a short term and a long term project has a different meaning. Sometimes the owners do not really own the time span they need, in some cases the original budget are estimated lower on purpose in order to get a project decision. This has been demonstrated for some historically important projects. Without those falsifications, we would not have St Peter in Roma nor St Paul in London, that were heavily underestimated at the beginning, it is not known whether on purpose: if the total cost were known from the beginning, nobody would make the decision to go on and the world, today, would be poorer.

On the other side, the Colosseum in Roma, whose construction lasted from year 72 to year 80, was erected quite on time and on budget.

Every project goes through a stochastic phase, where the project is still not fully defined and still is possible to cancel the project; afterwards the project becomes deterministic and, after the decision to start, it becomes quite impossible, or at least extremely expensive, to cancel it. To be fair, we should admit that no stochastic phase is fully stochastic, since there is always something deterministic and, on the other side, that no deterministic phase is fully deterministic.

The capability of the human being to foresee the future is extremely limited: most of the instruments we have only allow us to project the past data towards the future, sometimes with parametric indexes that allow for variations.

The historical data we have are generally not enough, in addition short-term statistical data and indicators are not effective when used for longer term forecasting. Furthermore, technology is evolving

and this can effect long term projects, for instance due to new investments needed, increase of productiveness, variation of availability and cost of resources):

- Innovation and new technologies will change the quantity of resource needed
- Projection of data can give a quite good idea of the cost for few years
- Major political or economic events, as well as «Acts of God» or «Acts of Government» can change the project framework
- Owner related events can lead to a change of the scope of the works

It is worthy to make some consideration on the very meaning of "long term project". In the case of a manufacturing company, normally "short term" means within the yearly cycle of the balance sheet, "medium term" means within the investment duration cycle (from 5 to 10 years, even more than 20 years for infrastructures or power generation) while "long term" means beyond the investment duration cycle). This to say that short and medium term are substantially deterministic while long term is substantially stochastic.

What about a project? It would be easy to say that a long term project is defined as a project whose duration is more than 7 or 8 years, this can be true for infrastructural projects but it is not a general definition, an IT project can be defined as a long term project if duration is more than 2 or 3 years.

We dare then to propose a new frameworks:

- ✓ **short term**: duration of activities and constraints fully defined, costs can be calculated with high reliability and a limited contingency margin
- ✓ **medium term**: constraints defined, durations can change not in a way to impact on the constraint structure
- ✓ **long term**: durations and constraints can change
- ✓ **undefined term**: besides constraints and durations, also the scope of the project can be adjusted during the project execution, sometimes there are changes in the vision of the owners and then in the goals to be achieved through the project

PLANNING AND SCHEDULING

Planning and scheduling long term projects cannot be performed with the usual methods as we use for short and medium term, this is to say that deterministic methods are not enough.

The most used deterministic method is the CPM (Critical Path Method) and its derivate such as PDM (Precedence Diagram Method) and METRA, that are fully deterministic and then not suitable for long term, sometimes planning and scheduling are only limited to work packages, that are in a further stage developed from time to time (rolling wave) as the project goes on and details become clearer, this is still a deterministic methods albeit organised into two levels and then with more possibility of being adjusted. PERT (Project Evaluation and Review Technique) is still a deterministic method, with the possibility to consider some durations with a stochastic approach.

The use of a proper, higher margin for contingencies and work variation can help up to a certain point, however it does not make any more sense if such margin becomes a substantial part of the estimated time and cost. If a project is planned to start 10 years or more, we need to use a fully stochastic planning method that allow the use of probability on constraints: even those methods would not help in case of a change in the scope of the works, that cannot neither foreseen nor controlled. Also the project framework can be modified due to owner related events or to major political events, as well as to causes normally considered as *force majeure*.

As far as the stochastic planning methods, as they are known in the operational research, we would like to remind:

- ➢ GAN (Generalized Activity Network), based on an equivalent network function that consider either the probability that an activity be actually performed or the change of its duration
- ➢ GERT (Graphic Evaluation Review Technique), that tries to simplify the stochastic network creating an equivalent reduced network, that can be managed as deterministic
- ➢ GERTS (GERT Simulation), that adds to GERT method the simulation

- VERT (Venture Evaluation Review Techinique), that is basically a further development of the GERTS.

In addition to those, other simulation as well as stochastic methods can be considered. In general, those methods need to be managed by experts in operational research, that is beyond the professional competence of a planner. However, some recent software initially created for deterministic scheduling allow stochastic routines and add-ons.

As far as costs are concerned, it is quite impossible to make a reliable assumption on the actual costs of a long term project if we try to make a budget adjusted through projected economic indicators, for the reason that shall be shown in the following paragraph. Useless to say, a further problem can be due to changes in the scope of the works. It is generally easier to plan the resources needed, whose amount is normally more stabilized, and then to adjust from time to time the amount of the invested money with the actual costs: this means than there is need of some flexibility in fund allocation as well as in the overall project budget.

It is enough to refer to the standards that are normally used for defining the reliability of project estimating, such as the ones from AACE International, ANSI Z94.0, ACostE, RICS (Royal Institute of Chartered Surveyors), British Petroleum, British Gas, Norwegian Project Management Association, American Society of Professional Estimators and others. If we refer, for instance, to the standards of AACE, estimating is classified into five levels whose reliability varies from -10/+15% for fully detailed project (level 1) with unit costs and bill of quantities fully known to -50/+100% for an order of magnitude estimate (level 5). Long term projects cannot be managed in a fully deterministic way, therefore cannot be considered neither in level 1 nor in level 2, while level 3 seem to be more applicable, with a -20/+30% reliability.

It is then necessary to consider that, in those cases, also budgeting becomes stochastic.

If the project starts undefined, in some cases the best way is to divide it into more subprojects out of which the first or the second are defined and, based on results of those, it would become possible to define the third, the fourth and so on. This is the case of major motorway or railway projects than can be divided in several sections to be put in operation one by one, being the other sections still not completed or even cancelled. The same has been applied to major space exploration projects such as Gemini ore Apollo; on the other side, a project like the bridge to connect Sicily to continental Italy cannot be divided into sections with the same criterion, since if only part of it is built it would become quite useless.

ECONOMIC INDICATORS

Any kind of forecast based on the value of economic indicators collected for the previous years is at risk of being completely wrong. As a matter of fact, economic indicators are normally based on a statistical analysis of a defined basket of goods, products or work processes. Those indicators are quite reliable in the short and medium term, sometimes up to 10 year time span if the procedure of data collecting and analysing is quite completed and statically correct, but they start to become unreliable if we try to utilise them for longer term economic forecast. The main reasons are:

- ✓ the basket of goods or services that are assumed as a sample has to be modified to remain statically significant, if it is not modified is at risk of losing the significance,
- ✓ the relative prices of goods and services are varying,
- ✓ the technology evolves,
- ✓ the productivity of manpower and equipment evolves too.

As an examples in year 1995 we had to calculate the equitable price for a railway maintenance workshop whose contract was stipulated on 1976 and suspended from then. The original contract value was 20 billion L.it[1] that, multiplied for the applicable index of 5.6, returned an updated amount of 112 billion L.it: actually this amount was claimed from contractor to complete the work. It was evident, at first sight, that such amount was extremely high, the problem we had to face was first to understand why and then to re-negotiate the contract.

When we investigated into the design, the bill of quantities and the unit prices we noticed that

[1] L.it = Italian Lira, the Italian currency before the Euro. The conversion ratio has been 1 € 0 1936.27 L.it

- ✓ the railway signal technology used in 1976 was different from the technology of the nineties
- ✓ the price list of 1976 was still calculated considering that the rails be installed by hand, while the pricelist of the nineties was based on mechanical installation
- ✓ the productivity of electrical installation works had had a sensible increase

Our conclusion was that a fair price for the workshop should have been in the range from 54 to 60 billion L.it (useless to say, contractor should have been entitled to some compensation for having been kept waiting for twenty years, but this consideration was beyond our scope of works).

EXAMPLES

Messina bridge

The bridge to connect continental Italy to Sicily has been one of the major projects in the first decade of the XXI century; the idea to connect Sicily to continental Italy was first brought forward by the Romans, then by the King of Two Sicilies in 1840 who ordered a feasibility study. In recent time, a project based on a design of a single-span suspension bridge with a central span of 3300 m plus road and railway links was actually awarded (2005) to a consortium led by the Italian company Impregilo SpA and then abandoned (March, 2006). The budget was about 4 billion euros in 2005, in 2009 the budget was again estimated in about 6 billion euros and the project was finally cancelled for lack of funds.

It is worthy to consider that the tender documents also included for a calculation of life cycle costs over a time span of 30 years plus an additional 30 years, for a total time span of 60 years. To let understand the difficulty and limited reliability of such estimation, we have considered the projection of economic indicators from the past by using regression methods and then comparing with the actual data. Some results are shown here below:

- ◘ if we simulate a projection made in 1891, based on 30 year data base and linear regression, for a project due to last until 1921 (30 years) the actual cost for the last year is 3.74 times the estimated cost
- ◘ if we simulate a projection made in 1951, based on 90 year data base and exponential regression, for a project due to last until 2011 (60 years), the actual cost for the last year is about 35.8 times the estimated cost

The reliability of a life cycle cost calculation for so long time is based on the assumption that no major change happens neither in the world as a whole nor in the structure of the economic system. The same will apply to sensitivity analysis, that makes sense for variations of the data taken into consideration until 10% or 20%, but would be spoiled if we take into consideration 50% or 100% variations.

Petrochemical plant in Middle East

A major petrochemical plant in Middle East was composed by 13 process units centred around a steam cracker, 6 utility units and a connecting network (off-site facilities) plus auxiliary facilities such as office building, internal roads, canteen, etc. The project was actually divided into four subproject named

- ✓ onsite (process units),
- ✓ offsite (connecting network),
- ✓ utilities,
- ✓ services.

Duration scheduled for construction was about 6 years, standard workload was about 16.1 million of SMh (Standard Man-hours).

No one of those sub-projects could exist as an autonomous project, then the term sub-project was misused. The project controls was based on a project schedule and on a budget, that were verified deterministically every month, by using a PDM network, the analysis of the critical path and the usual earned value criterion to compare the planned versus the actual cost. When the project went into delay and then to register cost overrun, although the assumption was still to use a deterministic method, the planners started to modify some constraints as well as the critical path in order to adapt the schedule to reality: this is to say that the planning became stochastic, notwithstanding the fact that such change

was never declared openly. In a further stage, the owner decided to cancel part of the project to cope with previously unforeseen economic difficulties. For doing this, it was necessary to redraw the structure of subprojects since it would not make any sense to keep the process units and to cancel the utilities. Simply, the plant would not work. By this way, the scope of the project was actually modified.

It is hard to say that the project has been kept under control, but at least a default has been avoided. In reality, it would have been better to consider this possibility since the beginning, by introducing the idea of a stochastic planning and by taking into consideration a more suitable division into autonomously sustainable sub-projects.

The medieval cathedrals

One paramount example of a long term project is a medieval cathedral (according to the most used definition of the term, however, it cannot be defined as a project since time and scope were undefined).

To have an idea about how those project were managed, we can refer to a modern project that is more similar to a medieval cathedral than to the projects we are usually taking into consideration in recent times. This is the cathedral of the *Sagrada Familia* in Barcelona, whose construction started in 1882 and has not yet been completed: however the church has been consecrated by pope Benedict XVI in 2010. The original design was from the architect Francisco de Paula del Villar, then a new design was made by the architect Antoni Gaudí, involved after construction was started. Other architects were involved after Gaudí death, in order to complete his design.

Since it is an "expiatory church", like most of medieval cathedrals, construction had to rely only on private donations and therefore there was not any possibility to make a reliable planning, the work packages were scheduled from time to time according to the funds available, the progress was less that 25% in 1926 (death of Gaudí) and was estimated as 50% about in 2010. The scope of the work was changed several times, the actual design is not anymore the original one and still there are undefined points and some technical challenges. However, millions of people are visiting and it has been declared part of the UNESCO World Heritage, notwithstanding the facts that it has not yet been completed.

According to a statement from Gaudí "*El Temple Expiatori de la Sagrada Família el fa el poble i s'hi emmiralla. És una obra que està a les mans de Déu i en la voluntat del poble*"[2]

CONCLUSION

A long term project whose scope is quite defined can still be kept under control, with proper methods, by adjusting from time to time the parametres to the actual change of the economic system as well as of the project itself.

An undefined project, whose scope is not fully defined, can be kept under control section by section, if the division into sections makes sense like in the case of the railway or motorway system or of the space exploration, id est to say when every section can be considered as a quite full project. If this does not apply, like in the case of the *Sagrada Familia*, the very idea of controlling the project makes no sense: as a matter of fact, in 1882 was impossible to make any assumption about time and cost, the design was quite undefined, in reality there was only the willingness to build a cathedral. Like in medieval cathedrals, design was modified again and over again during construction, parts were added or removed, dimensions modified. Even now, that the cathedral is already consecrated (business-like, we can say that it is in operation), it is not yet clear which shall be the final design.

[2] The expiatory church of *La Sagrada Família* is made by people and mirrors (The people). It is a work that is in the hands of God and the will of the people "

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