CONTRIBUTION TO THE MODELING OF THE EFFECT OF RISK ON A CONSTRUCTION PROJECT: COST FACTOR

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Abstract

Through a risk study, one provides for mastering the achievement of objectives. However, one should not think that objectives are supposed to remain stable throughout the implementation of a project, even at zero risk; Just the fact of carrying out a project will change its basic environment, and thereby the local or regional microeconomics; Therefore, a certain evolution of the cost, albeit minimum, must be admitted. This is where the importance of the risk study lies; it aims at developing a framework for such evolution, first and foremost to avoid that it pops up accidentally.

For this purpose, risk study brings forth a set of means grouped into RISK MANAGEMENT PROCESS (RMP).

RMP is set off at the base of risk identification, which represents the first phase of the process. Then RMP will focus on the classification, analysis, assessment and management of such risks, using various suggested models, which are concentrated around four ways to respond: transfer, acceptance, mitigation, avoidance.

Our study will draw upon the RMP which will offer as output the risk and the most optimal response to be assigned thereto. Our contribution consists in proposing a simplified model that allows to evaluate, starting from the cost overrun generated by a risk over a phase of the project at the moment of time (m), the cost overrun that will be generated over the other phases at the moment (m + 1) by the said risk. Starting from a function that will bind all the costs of the project.

Introduction

Risk refers to all cases of events that may generate a new, unexpected or unknown situation (Smith 1999; Seyed Mohamad & many others, 2011) which may stand in the way of attaining objectives. Reference is made either to risk taking, when one finds oneself compelled to confront a situation whose consequences or conditions are not mastered, (…) or to risk in general when during the project a sudden, new and uncertain external event usually appears, which impacts on the project, i.e. on its objectives (BREYSSE & many others, 2009).

However the fact of classifying a risky situation is very intuitive, because we do not all have the same faculties to classify a risky situation; for example, under-developed countries would still face risks which developed countries have long overcome (Eduardo Arturo, 2009).

On the other hand, all agree that there are two types of risks; Identifiable risks witch called foreseeable risks, they include, from a point of view, force majeure, which are usually defined in country laws (Eduardo Arturo , 2009). These risks could be modeled, using methods that estimate a numerical value for the risk starting from functions whose factors are: frequency or probability, impact, events and events combinations... (Hull, 1990 ; Williams, 1996). At the limit of and beyond foreseeable risks there are the unforeseeable risks. A multitude of research studies have as a single focus of interest to find the best ways to define the scope (limit) between what is foreseeable and what is not.

Consequently, most importantly before invoking risk, the defined objectives for a project must already be real and correct. It is then necessary to define a time for testing objectives and to admit that these objectives may evolve over time, As Jacques Chirac (1992) points out: 'In a changing environment ,there is no greater risk than standing still' (A new France, 1992).

Project cost & risk

A. Phasing a construction project

Cost determination bounds down to breaking the project down into several phases and making an inventory of all the stakeholders( ) likely to take part in the project; referring at each stage and with regard to each aspect of the project to the applicable regulations and the standards for each matter.

There are several ways to imagine the phasing of a project (Cooper & Chapman, 1987; Edwards & Bowen, 1998; Klemetti, 2006; Zhou et al., 2008; Eduardo Arturo, 2009; Taroun, 2011; & many others). Indeed, a construction project takes place over several distinct and successive phases; we propose:

- Phase1: Preliminary studies, feasibility studies, planning;
- Phase 2: Design and (technical) studies;
- Phase 3: Approvals, authorizations, fees, taxes...
- Phase 4: Construction work;
- Phase5: Acceptance, commissioning, registration.

Other functions are incorporated in the five phases above-named, such as: budgeting, preparing of specifications, consulting and tenders, contracting, management control and management.

A.1. Stakeholders in the project

Each phase involves a number of stakeholders or operators:

Table 1 : stakeholders by phases of project

	Stakeholder	Operations	Cost
Phase 1	- Client - Consultants - …	- Feasibility study -Preliminary costing - Budget - …	C_{Cl} + C_{cons}
Phase 2	- Client - Project Manager (Architect, Design & Engineering Firm(s), Consultants…)	Design, studies	C_{Cl} + C_{PM}

Phase 3	- Client - Project Manager - Administrations (Commune, Urban Agency…) - Concessionaires	- Authorizations -Taxes, contributions - …	C_{Cl} $+C_{PM}$ $+ C_{Ad}$ $+ C_{conc}$
Phase 4	- Contractor(s) - Client, Project Manager - Administrations - Concessionaires	- Implementation work - Follow-up & Control	C_{Cont} $+ C_{Cl}$ $+ C_{PM}$ $+ C_{Ad}$ $+ C_{conc}$
Phase 5	- Contractor(s) - Client, Project Manager - Administrations - Concessionaires	-Acceptance, commissioning, registrations (title deeds…)	C_{Cont} $+ C_{Cl}$ $+ C_{PM}$ $+C_{Ad}$ $+ C_{conc}$

A.2. Means to determine costs

To set the overall cost of the project, one needs mediums, such as:

- Agreements and contracts covering all services and all stakeholders;
- Standards in the relevant art, applicable Regulations (in order to know, inter alia, the fees related to various authorizations, taxation...).

The table below outlines the means for determining costs making up the overall cost:

Table 2: descriptions of project's costs

	Description	Means of Determination
C_{Cl}	Charges and expenses (wages, salaries and various costs) related to the project throughout its duration ($\sum T_{Pm}$)	- - Company's charges, law and labour code
C_{cons}	Consultant's cost may be subject to an order or contract determining the services planned and the corresponding fees	- Orders, contracts
C_{PM}	Cost of Project Manager (Architect, Design & Engineering Firm(s), Laboratory, consultant…) are generally subject to fixed-price or quantity contracts	- Contracts
C_{Ad}	Administration costs include: - Authorization fees (calculated on the basis of the surface areas to be constructed or developed) - Taxes: ○ Fire Brigade ○ Real estate registration ○ Right of way in or temporary operation of public property	- Agreements, regulations, codes, laws…
C_{conc}	Costs of concessionaires, who may be operators of water, electricity, gas networks or otherwise; their fees often correspond to: - Expenses of participation to existing (possibly future) networks - Connection and supply expenses (provisional and final meters) - Fees for effort and care - Other: various taxes	- Regulatory agreements, laws, quotes…
C_{Cont}	Cost of work (including any constraints at the contractor's expenses: insurance…)	Contracts

B. "Cost" as an objective

B.1. Total Cost

The total cost of the project is the sum:

$$C_T = \sum C_X, \quad X = [1{,}5]$$

Where C_X is the cost of phase x.
Total cost depends on time; indeed as the project progresses $(t_m, m = [1, T_G]$, C_X may take on different values, i.e.

$$C_T\,(t=0) = \sum C_X\,(t=0), \quad X = [1{,}5]$$

where $C_X(t=0)$ is the cost of phase x rated at the time $t = 0$, which in our opinion should correspond to the moment when all contracts have been concluded, including with the work contractor, and the authorization to start work, with all what it is supposed to include (payment of various fees, taxes, royalties,...) is granted.
It is at this moment that the objectives are tested.

B.2. Cost taking into account foreseeable events

Indeed, experience has shown that, (Chen Huali, 2007)

$$C_X(t=0) \neq C_X(t=m) \neq C_X(t=T_G)$$

I.e.,

$$C_X(t_1) = C_X(t_0) + \Delta C_X(t_0)$$
$$C_X(t_{m+1}) = C_X(t_m) + \Delta C_X(t_m)$$

Therefore,

$$C_T\,(t=T_G) = C_T(t=0) + \sum_{X=[1,5]}^{m=[1,T_G]} \Delta C_X(t=t_m) \quad (1)$$

where, $T_G = \sum T_X, X = [1{,}5]$, Combination of time for the performance of the tasks of all phases.

$\Delta c_x(t_m)$ represents the increase or decrease of $C_X(t_m)$ calculated at the moment t_{m+1} which is due to events that are supposed "foreseeable" by stakeholders in the project;
C_X is subject to adjustment at any time of the project; it is final only upon project completion (i.e. at $t \leq T_G$);
Indeed, an event that may occur at the time interval [t3, t4], corresponding to the completion of phase 4, could result in an effect on the production cost of phase C1 being completed in time [t0, t1]. Therefore, the total cost should be regenerated.
Examples:

- Modification of the operation program:
- The Project Manager's contracts provide that modifications may be introduced into the project in the course of work, without the Project Manager refusing to carry out adaptive studies related to modification, on the understanding that payment will be made for the additional work.
- Modification of the constructed area or the volume of work:
- The PM is usually paid on the basis of the constructed area or the percentage of the volume of work actually performed. Ditto for the costs of the administration and the concessionaires; they will follow the work actually performed.
- This makes explicit the fact that the costs of phases C2 (Cost PM) and C3 (Cost of Administration...) are final only upon completion of work (i.e. after the establishment of the as-built plans duly signed by the Project Manager, and if necessary by a chartered surveyor).
- Modification of a standard: (*)

In the year 2004, when the earthquake disaster of Al Hoceima (town in the east of the country) occurred, where hundreds of deaths and injuries were reported, Morocco introduced a new law on earthquake-resistance, which also covered constructions under implementation at that time (the law replaces regulations dating back to 2002, providing for five seismic areas instead of three, and three classes of buildings instead of two): As a result, the production costs of all the phases of a project (any construction project, in general) changed: C1: Cost Cl for extra time generated by the modification; C2: Cost PM for going back over studies; C3: Cost of the Administration for resubmission of files for approval and authorization; C4: increase in the volume of work: reinforcements..., going back over the implementation studies; C5: total floor area having been changed: additional charges for registration with the real estate office...

- Exceeding the time limit for reasons attributable to the Client.
- The Contractor becomes entitled to charge penalties for delay in the form of price review, for example.
- Etc.

A similar reasoning applies to the time limit.
So far we still do not mention the word risk. As a matter of fact, the more possibility we have to predict events, the further we push the risk.
On the other hand, we conclude that the phases and their costs are interdependent; a cost variation introduced in a phase will affect the costs of the other phases. To this we will propose a simple equation to quickly calculate the additional (+/-) costs to be anticipated in the other phase(s) starting from the cost generated on the current phase.

B.3. Cost taking into account unforeseeable events: Concept of Risk

Experiences have shown that (MAO Mingfa,2008) (MA Wei-zhen, LI Zhong-xiang,2008) (Nimita A.Tijore, Dr. Neeraj D. Sharma,Mr. Hiren A. Rathod,2013) the real cost of a project (cost at the end of the project $t = T_G$) is not only the value (1), but in fact a (positive or negative) variation ΔCn which pops up. It is due to the development of unforeseeable events.
This implies that,

$$C_T\,(t = T_G) = C_T(t = 0) + \sum_{X=[1,5]}^{m=[1,T_G]} \Delta C_X(t = t_m) + \Delta C_n \quad (2)$$

ΔCn could impact on all phases; thus the cost calculation formula is to be adjusted as follows:

$$C_X(t_{m+1}) = C_X(t_m) + \Delta C_X(t_m) + \Delta C_{nx}(t_m)$$

where $\Delta Cn_X(t_m)$ is the variation in the cost of phase $C_X(t_m)$ calculated at the moment t_{m+1} under the effect of unforeseeable events (the Risk)
Otherwise,

$$C_T = C_{T0} + \Delta C_{T0} + \Delta' C_{T0}$$

where,

ΔC_{T0} is the variation of C_{T0} due to foreseeable events (efv), $\Delta' C_{T0}$ is the variation of C_{T0} due to unforeseeable events (eufe).

I.e., for each of the phases,

$$C_1 = C_{10}\,.(1 + a_1 + a_1')$$
$$C_2 = C_{20}\,.(1 + a_2 + a_2')$$
$$C_3 = C_{30}\,.(1 + a_3 + a_3')$$
$$C_4 = C_{40}\,.(1 + a_4 + a_4')$$
$$C_5 = C_{50}\,.(1 + a_5 + a_5')$$

Thus, knowing a_X, a_X' ..., we can estimate C_X and thereby C_T (total cost at the end of the project, taking into account foreseeable and unforeseeable effects).
Thus, we have at the moment T_G

$$C_T(t = T_G) = C_T(t = 0) + \sum_{X=[1,5]}^{m=[1,T_G]} \Delta C_{X,t_m} + \Delta C_{nx,t_m} \quad (3)$$

ΔC_n in the formula (2) will tend to 0 when $f(eufv) \rightarrow f(efv)$

Numerical model

Let's stop at observation (*)
Starting from the equation (2)

The following approximations are admitted (findings from the study of the costs of hundreds of construction projects (industrial construction type),

$$C_1 = 4\%\, C_T$$
$$C_1 = 8\%\, C_T$$
$$C_1 = 3\%\, C_T$$
$$C_1 = 82\%\, C_T$$
$$C_1 = 3\%\, C_T$$

That is, phase 4 corresponds to the cost relating to construction work which involves more expenses. It is therefore subject to variation risk more than the other phases.
We may conclude that,

$$\frac{a_2 + a_2'}{P_2} = \left({C_{10}}/{C_{20}}\right).\frac{(1 + a_1 + a_1')}{P_1} - 1$$
$$P_1 = 4\%, \qquad P_2 = 8\%,$$

Similarly,

$$\frac{a_3 + a_3'}{P_3} = \left({C_{20}}/{C_{30}}\right).\frac{(1 + a_2 + a_2')}{P_2} - 1$$

And,

$$\frac{a_X + a_X'}{P_X} = \left({C_{(X-1)0}}/{C_{X0}}\right).\frac{(1 + a_{X-1} + a_{X-1}')}{P_{X-1}} - 1 \quad (4)$$

Example:
At the moment t_0 ,
$a_1 = a_1' = a_2 = a_2' = \cdots = 0$ At t_1, assuming the occurrence of a first, unforeseeable risk, i.e.
$a_1 = 0$
If,
$C_{10} = 22\ 700\ \$$
$C_{20} = 45\ 300\ \$$, (known at t_0)
$a_1' = 0{,}006$
$a_2' = 0{,}00822$
The “supposed” overrun cost of phase 2 at the moment t_1 , under the effect of the risk having generated additional cost $0{,}006.C_{01}$, on the cost of phase 1 is $0{,}00822.C_{02}$, evaluated at the moment t_1.
By analogy, for the whole costs, a_X (at the end of the project) $= \sum a_{Xm}, m[0, T_G]$.

Conclusion

This equation, which can be generalized regardless of cost distribution, is however limited to a few applicable cases.
We seek to conclude that the more total cost is divided into several sub-costs, the more risk is under control. Through the equation, it would be possible to easily regenerate the total cost at any instant of time in the project.

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