[Article] Dynamic Management of Risk Contingency in Complex Design-Build Projects

Original Citation:
De Marco, A.; Rafele, C.; Thaheem, M.J. (2016). *Dynamic Management of Risk Contingency in Complex Design-Build Projects.* In: JOURNAL OF CONSTRUCTION ENGINEERING AND MANAGEMENT, vol. 142 n. 2, pp. 1-10. - ISSN 0733-9364

Availability:
This version is available at : `http://porto.polito.it/2619254/` since: February 2016

Publisher:
American Society of Civil Engineers

Published version:
DOI:10.1061/(ASCE)CO.1943-7862.0001052

Journal of Construction Engineering and Management

Dynamic Management of Risk Contingency in Complex Design-Build Projects

Alberto De Marco, PhD

Associate Professor

Dept. of Management and Production Engineering, Politecnico di Torino

Corso Duca degli Abruzzi 24, 10129 Torino, Italy

Corresponding author: alberto.demarco@polito.it

Carlo Rafele

Full Professor

Dept. of Management and Production Engineering, Politecnico di Torino

Corso Duca degli Abruzzi 24, 10129 Torino, Italy

carlo.rafele@polito.it

Muhammad Jamaluddin Thaheem, PhD

Assistant Professor

NIT-SCEE, National University of Sciences and Technology

H-12, Islamabad, Pakistan

jamal.thaheem@nit.nust.edu.pk

Abstract

Contingency budgets are commonly used by managers to respond to uncertainty and control the project within the original cost and schedule targets. However, a variety of project participants with conflicting interests creates tensions when it comes to managing the risk contingency escrow account during the project development, and divergences often arise over the need for either retaining the unspent contingencies for future risk and improved facility, or releasing it as a profit.

With the purpose of studying the dynamics and main influences involved in the risk contingency management process of a Design-Build (DB) project, a System Dynamics (SD) contingency management model is proposed to simulate the decision making scenarios under different project conditions, and behavioral pressures of senior managers and owners. The model suggests that an aggressive proactive risk management practice might be an effective policy for managing the contingency budget in a complex Engineering, Procurement and Construction (EPC) project.

Introduction

An effective Project Risk Management (PRM) practice is critical to the success of complex projects. A PRM process typically helps to predict uncertainty so that risks can be either via preventive actions or reacted via ex-post corrective actions. Risk contingency plans are widely used tools and contingency funds are usually estimated at the project planning phase and included in the original budgets as escrow accounts to be used as a flexibility to manage uncertainties and risks that may deviate the project from its original time, cost, and quality objectives. Nonetheless, contingency budgets have to be estimated and revised during the course of the project as a continuous and dynamic management process. The contingency management process should be emphasized within the project management framework with the ultimate goal of protecting the interests of the various project participants, including owners, investors, creditors, top managers, and the community. The contingency reserve accounts must not be seen only as future costs for unforeseen events, but also as potential opportunities for releasing the unspent contingency as a profit or as added improvements to the constructed facility.

However, the contingency management process is often misunderstood by the majority of project managers (PMs) and limited to the task of analyzing risk during the planning phase only. Also, conflicts and divergences often arise between PMs, senior managers, and other stakeholders involved in the control process over the need for retaining the unspent contingencies for future risk response or releasing the excess contingency as a profit and reduced price to the client, such as in the case of target cost plus incentive fee type of construction contracts (Weston, 1999).

While managing a project, it is often challenging for managers to determine if it is safe to allow the client to draw from the contingency escrow account of an ongoing project or if it is opportune to release as profit a certain amount of past unspent contingency.

The common sense might suggest a relationship between the project progress and the need for maintaining contingency reserves. However, complex projects rarely live up to this pragmatism, and PMs' approaches differ from expectations. In this context, understanding the ways in which managers approach the problem of managing the contingency budget is an important issue in order to design and implement effective PRM processes.

Now, despite development over the last decade of international standard guidelines (IPMA 2006; PMI 2009), scholarly papers and professional practice in the arena of PRM, there is still limited help for PMs in improving the contingency management process during the project lifecycle. Most PRM literature focuses on the processes of identifying and evaluating contingencies, but little effort has been put at understanding the influences of belief and behavior of the persons in charge of managing the contingency management process. While the risk planning process is now largely used in most organizations and complex projects, formal standard models for the contingency fund management are perceived as ineffective and are built ad hoc for specific projects (Kutsch and Hall, 2005). Moreover, the literature does not describe how contingencies are managed during the project lifecycle and the impacts of different contingency management strategies on project performance are not investigated, thus offering little help.

In order to contribute to overcoming the research gap, the purpose of this paper is to develop a cost contingency management model to help PMs understand how to more effectively manage the contingency budget during the project lifecycle under the influences of various project participants who are willing to either keep an escrow account for dealing with future risks or release the excess contingency as a profit for the benefits of owners and corporate performance. In particular, the model is developed using systems thinking and System Dynamics (SD). Based on a previous model proposed by Ford (2002), the present model adds the managerial influences of the main project participants and investigates the behavior of contingency management process over the sequenced but overlapped phases of engineering, procurement and construction (EPC) involved in complex DB contracts.

The paper is structured as follows. Firstly, available literature is presented to set the problem, along with a brief recall of the SD theory and presentation of the originating model. Secondly, the research methodology adopted for the paper is given together with an overview of the usage of contingency budgets in DB contracts. Thirdly, the SD model is presented. Then, a quantitative analysis of the model's simulations is given. Finally, results are discussed with policy recommendations and main implications followed by future research directions and conclusion.

Review of Pertinent Literature

Cost contingency in complex projects has been a research topic for long. A large share of debate has been dealing with proposing and applying suitable methods and techniques for estimating the contingency reserve (Idrus et al. 2011; Tseng et al. 2009). The contingency budget can be referred to as the amount of money within the cost baseline that is allocated for identified risks that are accepted and for which contingent or mitigating responses are developed (PMI 2013). Typically, to avoid deviations from the baseline finances (Harper et al. 2014), contingency budgets in complex projects are allocated either using qualitative and semi-quantitative techniques (Mak and Picken 2000; Günhan and Arditi 2007) or probabilistic (Thal Jr. et al. 2010; Khamooshi and Cioffi 2009) and simulation-based methods (Sonmez et al. 2007).

However, just a few contributions are available when it comes to understanding three important aspects, namely: the process of managing the contingency during the successive stages of project development, the managerial pressures imposed by the project participants, and the dynamic behavior of the contingency accumulation and release process.

As far as the first issue is concerned, Mills (2001) recognizes the importance of systematic risk allocation approaches and suggests that risk needs to be identified and managed during the project lifecycle and especially during the procurement process. With this regard, Xie et al. (2012) present a method based on Value at Risk for project cost contingency updating at project milestones during the project execution and for allocating appropriate contingencies at different project phases. Also, Barraza and Bueno (2007) state that due to the variable performance nature for a wide range of activities, contingencies should not only be properly calculated but also assigned in the budget estimation process and wisely controlled during the project execution. To this end, they recommend the Monte Carlo simulation approach as a methodology for cost contingency management. Finally, Seyedhoseini et al. (2009) debate around the techniques that help select the appropriate risk response actions via an application in construction projects.

With regard to the research area associated to capturing the influences of the various stakeholders affecting the contingency management and decision making processes, it has been largely recognized that based on their points of view, different project participants construe the characteristic and function of contingency differently (Baccarini 2005). However, little contribution is available to help understanding such mechanisms. One paper that is helpful for the present work is given by Del Cano

(2002) who presents a PRM process that has been particularized for construction projects from the point of view of the owner and the consultant who may be assisting the owner. Also, the work by Osipova and Eriksson (2013) explores the importance of collaboration between the project actors in managing risks and investigates the tradeoff between control- and flexibility-oriented risk management strategies.

Lastly, major contributions to the study of the dynamic behavior of the contingency management process come from the systems thinking approach and the SD theory applied to project management (Lyneis and Ford 2007).

SD provides powerful concepts and medium to understanding and simulating the complex systemic behavior and the dynamic nature of complex projects (Mingers and White 2010). SD models are based on the causal feedback loops that either reinforce or balance complex relationship between the system variables (Richardson 2011). SD also offers a computer-based simulation environment that allows the modeler to graphically represent a system of differential equations and to have the computer do the discrete-step computational effort over a preset timeframe (Sterman 2000). The outcome of simulations is the set of curve lines that describe the behavior of variables on the time axis. This allows capturing the overall dynamics of the system, the influence of independent and dependent variables to the problem, and, finally, supporting decision making and testing policy design by making case-scenario simulations.

As part of the SD stream of research, an important work is the dynamic behavioral simulation model by Ford (2002). His model is an attempt to understand how managers make budget contingency decisions and how these decisions impact the project performance.

Finally, SD is an opportunity for including the managerial influences since complex systems may involve multiple stakeholders and decision makers with conflicting interests for which the SD provides viable problem solving tools (Kwakkel and Pruyt 2013).

Research Framework

Methodology

The present research was carried out as follows.

First, the contingency budget management process was investigated. This was done via an integrated analysis of available standards provided by international Project Management recognized associations (PMI, IPMA, PMA, etc.) and the pertinent scholarly literature, as reported in the previous section. In particular, an analysis of SD literature on contingency management was developed based on the idea that it is a consistent and conducive methodology to deal with this topic (Kapsali 2011). A special focus was given on the model by Ford (2002), which is the foundation for this work.

In addition, interviews were conducted with a select panel of experts to understand the managerial influences and diverse interests of the project participants. In particular, we interviewed the owners, senior managers, and PMs of three major complex EPC projects developed by an international design-builder with headquarters in Italy who here claims for anonymity. The three projects are to develop infrastructure and social facilities, namely: a large hospital building in Italy, a main highway bridge in Turkey, and a major hydraulic power plant in Peru. More details cannot be disclosed due to confidentiality reasons. Unstructured interviews were conducted during a two-year long PRM training campaign during which the authors acted as mentors and consultants to the company for improving and implementing a consistent contingency management process.

Second, the model was developed using the SD methodology (Sterman 2000) as described in the literature review section. Compared to the Ford's model, the most important features newly added to the present model are the managerial influences and the EPC phasing. Such components are added with the purpose of better understanding the contingency management process and engaging in a comprehensive improvement of mental models. On one hand, the proposed model includes the various managerial influences to contingency release decision making and diverging interests to the excess contingency usage strategies. The Ford's model contemplates that the contingency decision is totally in the hands of the project manager (PM) only. Here, both the senior management and the owner's influences are incorporated. They are the most powerful stakeholders and have adversarial and typically contrasting interests to the PM as they oppositely enforce the PM's decision to release the excess contingency as profit.

On the other hand, the model is developed over the sequenced, but partially overlapped, EPC phases of a complex construction project and assumes that the excess contingency is created and managed at the end of each phase so that management can direct the surplus budget of each phase to profit or cumulate it to the downstream phase.

Then, to verify for the robustness and sensitivity of the model, various case-scenario simulations are run using real data from selected projects.

Finally, based on select simulation runs, policy-making suggestions are drawn as a contribution to help improving contingency management models.

Contingency usage in DB contracts

Based on international standards, variations and adjustments to the contract scope of work are allowed in DB contracts. In particular, the owner has right to vary the scope of work within the boundaries of the contractor's capability, safety or performance, whereas the contractor may propose value engineering solutions to reduce the cost of works (FIDIC 2000). In other words, the owner may seek for facility improvements within a certain available budget cap and the contractor's top management may look for increased and early profit from the project to show the investors market of growing value. However, the two processes interact and largely modify according to the payment scheme agreed upon a DB contract.

If a lump sum firm fixed price is agreed, no significant interaction is activated between the parties' contingency management processes. In fact, the owner would control that the predetermined levels of quality and performance are assured, while the contractor's savings that can be created out of the engineering and procurement phases are just managed through the conflicting perspectives of the PM and senior managers.

However, under the contract conditions of a target price plus incentive fee, the owner, PMs, and senior managers interact to negotiate the contingency release (Weston, 1999). In this case, savings created as a consequence of design and procurement must be shared between the owner and the contractor: first, the release decision must be taken, then if savings are released the owner may order for facility improvements for as much as her share of released cost savings.

The proposed model can be purposely applied to simulate the various situations of a firm-fixed price or a cost plus saving-shared fee (Gordon 1994), whereas its use may be limited or inapplicable when pure cost plus percent fee or unit price payment schemes are in place.

The Model

General structure

The model developed using the VensimDSS® software can be described as composed of three sections associated to the three main EPC development stages of a DB project: each section is linked to the downstream stage from engineering to construction via the stock and flow modeling of profit and excess contingency allocation. In turn, each section is a modified replication of the Ford's (2002) model with added modeling features of the downstream and upstream flows of excess contingency to and from the various stages of an EPC project and the PM's decision making process under the stakeholders' influences. In particular the model introduces the willingness to use the contingency for facility improvement by the PM, the top management pressure to release the excess contingency as profit and the owner's pressure to reallocate the excess contingency downward to improve the facility (Figure 1).

Figure 1. The subsystems

In turn, each section can be described as composed of four main subsystems, namely: escrow accounts, emergencies, schedule control, and facility improvements subsystem, as given in Figure 1 and described by Ford (2002), where the structure and detailed description of the subsystems can be found. The escrow accounts subsystem describes how contingency funds raise and decrease, and how they are dynamically reallocated as a flow of funds between the various contingency spending and releasing options. The emergency subsystem replicates the reduction of uncertainty through the rate of discovery and resolution of emergencies as a function of the project's progress. The schedule control subsystem models the accumulation of the project's delay as a function of the ability and speed at which the PM adjusts schedule and reduces the time delay, and as a function of the level of managerial acceptance of a delayed completion of the project. The facility improvement subsystem reproduces the increase in facility value due to the accumulated use of contingency for improvements (Ford 2002).

Model of the managerial influences on the excess contingency

In addition, here we model the pressures that senior corporate managers and owners impose on the PMs' decision on how to deal with the surfeit contingency escrow account and the associated process of streaming the excess contingency towards successive stages or the profit account.

Following are the main hypotheses underlying the contingency influence model. During the engineering stage, the owner's attention on the project output is typically very high due to her need for compliance between the detailed design and the original requirements and contract specifications. At this phase, conflicts arise between owner and contractor because of diverging interests: the owner would tend to include all possible improvements to the facility as an effect of careful and generous design as risk prevention, while the contractor would seek for savings via alternative design solutions and cheaper construction methods (Doloi 2012). At the engineering phase, the pressure imposed by the top managers to release the excess contingency as a profit is very high, but so is the pressure by the owner to use the potential contingency savings for improved facility.

During the procurement stage, the PM can secure major savings in buying cheaper materials and services, as well as in obtaining large excess contingencies from a timely and careful management of subcontractors, suppliers, and supply deliveries. The senior management typically requires that the excess contingency is returned as profit, while the owner would seek any contract clause to get procurement and supply management savings used for either obtaining a reduced price, if the contract allows, or for added facility improvements. However, the PM would try to keep the contingency for emergency management and schedule control and, on the other hand, as an added reserve to protect the project from most of the risks that typically occur or impact late into the construction period and that are likely to jeopardize the expected timely completion and the cost/quality performance tradeoff of the project.

According to these hypotheses, the rate at which the excess contingency at each EPC phase is released to profit is modeled as per Equation 1.

*Contingency budget released to profit rate = (Excess contingency account/Remaining duration of phase)*Top Management Pressure on PM* (Eq. 1)

In Equation 1, the senior management's pressure on the PM is assumed as a linear factor from 0 to 100%, with zero indicating no persuasion and 100% the maximum possible influence imposed by senior managers on the PM's decision.

As a consequence, the rate at which contingency funds are accumulated to the downstream phase's contingency escrow account is complement to the total excess contingency account rate, deducted the rate of contingency used for improvements under the owner's influence as per Equation 2.

$$\text{Excess contingency added to downstream phase rate} = \text{Excess contingency account rate} - \text{Excess contingency released to profit rate} - \text{Reallocate the excess to improvement rate} \quad \text{(Eq. 2)}$$

As far as the owner's influence on the PM's decision making is concerned, this is modeled in the improvements subsystem as per Equation 3: the rate at which the value is added to the facility improvement (noted as V_i in Equation 3) equals the use of the contingency for the purpose of improvement (u_i) times the effect of the project progress on facility improvement efficiency (f_i), multiplied by the owner's pressure. The facility improvement efficiency is in turn defined as the ratio of value added per dollar of contingency spent on improvement. It can be observed that the value added by each dollar of spent contingency decreases as the project activities unfold.

The owner's pressure is defined as a dimensionless variable from 0 to 100%. The maximum value of 100% represents the corresponding influence on cumulating the excess contingency to the facility improvements account.

$$\left(\frac{d}{dt}\right) Vi = u_i * f_i * \left(\frac{t}{t_t}\right) * Owner\ pressure \qquad \text{(Eq. 3)}$$

These influence relationships are applied to all three EPC sections, and both top management and owner's pressures can be given different values at the various phases in each simulation scenario for the purpose of evaluating the different hypotheses and proposing contingency management policies.

Accordingly, a schematized model of the influences on the contingency management process is given in Figure 2. The complete list of equations and the Vensim® model are available as supplemental data.

Figure 2. The contingency budget management influence model

Simulations and Findings

Select simulation case-scenarios

This section provides some SD simulations and shows their graphical representation: some relevant and most informative case scenarios are introduced and discussed.

To run simulations, the following main assumptions are used to ensure simplicity of analysis. The total contingency funds for the three lifecycle stages are assessed and made available at the beginning of the project. The decision making time for the PM, referred to as the time to resolve emergencies or adjust the schedule, is kept constant along the full lifecycle. The time and cost to solve emergencies is kept constant, as well as the unit cost for schedule control. The relative inherent importance of pressure felt by the PM is considered same and constant over time regardless whether it comes from the owner or the senior management. However, for sake of practicality, the model may run under more realistic conditions such as variable time to make decisions or adjustments.

Also, based on the study of the select three actual case projects, the EPC phases are assumed as partially overlapped. In particular, the case projects under consideration have similar approximate duration and sequencing as per the following. The engineering phase lasts for the first half of the project duration (24 months). After 8 months, the procurement process begins until almost the end of the project so that it results to be largely overlapped with construction. The construction process then starts when the engineering duration is 50 percent complete and it goes on until the project completion. Simulations run for as long as 48 months which is the average length of the case projects.

Also, to reflect the PMs' behaviors during the lifecycle of the case projects, the PM's willingness to use the risk contingency for schedule control is assumed as a stepped constant; increasing at each successive stage, such as 0.1, 0.5, and 0.9 during the engineering, procurement, and construction phases respectively. These figures are assumed to be a good numerical representation of the escalating schedule slippage that PMs face in real life scenarios and, in particular, in our three selected cases. In fact, as far as the project activities and phases unfold, the project tends to cumulate unforeseen delays that require spending the excess contingency to be recovered.

The values to these variables can be entered directly by the user in the modeling software interface so that a base scenario is created. Then, using all these assumptions and their associated input data as described above, some relevant and informative case-scenarios are presented in the following sub-sections with different levels of stakeholders' pressures in order to test the contingency management influence model and draw potential policy implications. The case-scenarios are obtained by running multivariate simulations using the theoretical input data given in Table 1 that represents the level of managerial pressure imposed by the stakeholders on the PM and the willingness of the PM to use the contingency for substantial improvement to the facility.

Table 1. Input influence variables for select relevant case scenario simulations

According to Table 1, four hypothetical case-scenarios can be described as follows.

First case-scenario: high willingness to improve the facility and low owner's pressure

The first case-scenario intends to simulate a steady and quite high predisposition of the PM to make substantial improvements and additions to the constructed facility at all three stages of the project development. Under such scenario, the owner does not press to the improvement objective (10%) and the top management pressure to release excess contingency increases as far as the project tasks unfold, shifting from an initial 10% to a final 90% of the maximum managerial influence to release the excess contingency as profit. This scenario does not represent any conflicting pressure from the opposite stakeholders due to lower owner's pressure. Figure 3 presents the cumulative amount of excess contingency that is released as profit under such conditions at the three EPC stages. It is shown that little contingency is released during the engineering process, while a large portion of the margin is made available by converting the risk contingency into profit during the procurement phase, likely due to major cost savings created via materials and supply optimizations, and the very last portion of the construction period, when PM becomes confident that not all the contingency will be spent for dealing with unexpected risk as per the upcoming successful completion of the project.

Figure 3. Amount of excess contingency released as profit under case-scenario 1

Second case-scenario: medium willingness to improve the facility and decreasing owner's pressure

The second case-scenario simulates a non-conflicting situation with decreasing owner's pressure and increasing top management pressure as the project progresses. This means that the owner's influence is greater than the senior management pressure during the engineering step, while the senior management's pressure becomes more influencing during the construction stage. This scenario is tested under a medium level of willingness of PM to make improvements to the constructed facility. The non-conflicting nature of this scenario is due to shifting balance in pressure by owner and top management with a constant PM's willingness to use contingency for facility improvement. Figure 4 reports the associated simulation graphs.

Figure 4. Amount of excess contingency released as profit under case-scenario 2

In particular, it shows that the initial influence of the owner to add substantial improvements to the design/engineering of the facility leads to reduced accumulation of released contingency at the procurement level and in total a lower level of contingency is transformed into profit, even if the PM has little predisposition to make improvements to the facility.

Third case-scenario: high willingness to improve facility and high owner's pressure

Third scenario simulates the strategic alignment between the PM and the owner: high owner's pressure during the total lifecycle is imposed under a high PM's willingness to make improvements. This leads to a large use of contingencies for facility improvement and careful project management to meet the quality and time targets, but little attention is in turn routed to making profit for the company. However, a conflicting and mounting senior manager influence to release the excess contingency as profit has been enforced. With progressive phases, the top management is getting weary of alliance between the PM and owner who are making maximum utilization of contingency over the project. As a result, Figure 5 shows that a large portion of the contingency is spent for emergency management, schedule control and facility improvement to mitigate and prevent future risk with the purpose of assuring a successful, timely and improved completion of the project. However, the imposed senior management stress would tend to maintain a steady conversion into profit of a limited, but sure, unspent contingency. This appears to be a conservative management practice leading to lower but sure profit: an acceptable low risk, although low profit tradeoff.

Figure 5. Amount of excess contingency released as profit under case-scenario 3

Fourth case-scenario: low willingness to improve facility and high owner's pressure

Finally, the fourth case-scenario simulates a low willingness to use the contingency for the facility improvement and strong owner's pressure conflicting with the high pressure forced by top management. In this situation, there is no a strategic alliance between the PM and the senior management at ensuring maximum profit in the form of unspent contingency. However, the high owner’s pressure causes a decision making dilemma. The associated Figure 6 shows that senior managers’ influence prevails due to being reconciled with the PM’s predisposition to avoid using too much contingency for schedule control and facility improvements. As a consequence, most of the contingency is released as profit since the engineering stage to provide for the greatest benefits at the corporate level. However, this ends in no more profit released at the construction phase, because it is likely that the little remaining contingency will be mostly used for emergency and schedule control during the construction period. In other words, no improvement is made since the beginning as risk prevention creates conditions for expensive reactive risk management at the end of the project.

Figure 6. Amount of excess contingency released as a profit under case-scenario 4

Comparison of case-scenarios and interpretation of results

Some considerations arise from comparing the proposed four case-scenarios and, particularly, from analyzing the different profit accumulation profiles as illustrated in Figure 7. Nevertheless, the various influence models do not only affect the contingency accrual and release process, but also shape the PRM strategies.

Figure 7. Comparison of profit release profiles in the four different case scenarios

Scenarios 1, 2, and 3 can be considered as applications of various risk-aggressive active strategies, while scenario 4 is an example of a conservative passive PRM policy.

In the first case-scenario, the PM drives an aggressive strategy. Here, profit is accumulated mostly during the procurement period as a result of spontaneous engineering/design improvements activated by the PM in a way that the contingency is largely spent for design improvements even if not forced or specifically requested by an active owner pressing to that objective. This is then reflected into advantages and major savings that a careful engineering activity drives into the procurement task. As a lesson learnt, in such active option a careful engineering phase is a risk mitigation policy to protect against future risks. In particular, a large portion of the engineering contingency is spent to improve the project as a risk prevention and flexibility to minimize future risks that may occur late into the project.

The second case-scenario is also an example of an aggressive strategy driven by an active owner imposing high pressure to use the contingency for improving the facility and mitigating future risks via expensive design solutions and risk preventive actions, regardless whether risk will occur or not. The simulation indicates that the owner should trigger responsible influence at the beginning of the project, i.e. during the design/engineering phase, while pressures made later into the project execution become less effective and somehow counterproductive.

Then, the third case-scenario is an example of an overactive strategy led by both the PM and the owner, aligned to the goal of improving the facility and activating expensive preventive risk management practices through spending a large portion of the estimated contingency since the engineering period. This case-scenario drives very low risk due to a lot of spending of the contingency for prevention and mitigation all along the lifecycle. But this also results in very little profit released with corresponding limited benefits provided to the corporate economic performance. It can be interpreted that the facility improvements are shared and distributed along the project both as flexibility against future risk, but also as a way to maintain good contract relationship and strategic alignment with a very demanding owner.

Out of these three scenarios, the first one provides for the greatest released profit: the autonomous predisposition of the PM to use contingencies for improvements as a self-directed risk-mitigating preventive strategy appears to be fruitful later into the project and able to reduce later risks so that the contingency is progressively released as profit. The proactive option when the PM, with little influences imposed by senior managers and owners, activates levers of early risk prevention to reduce expensive late risk reaction is suggested as an appropriate “worse-before-better” contingency release management policy (Repenning and Sterman 2001).

On the contrary, the fourth case-scenario is an example of a passive conservative project management policy where risk is ignored at the beginning and then reactively managed later into the course of action, if it occurs. In fact, this case-scenario shows that the contingency is not spent during the engineering period for improvements, while the majority is released as profit since the very beginning. As a consequence, little profit eventually remains because the residual contingency has to be used during the construction phase to deal with emergencies and react to unexpected risk. This conservative strategy may then jeopardize the successful completion of the project and lead to major cost overruns and time delays accumulated by the end of the project execution. In other words, such risk reactive response strategy would not play a role in mitigating the negative impact of project risks (Miller and Lessard, 2001).

Practical application

In order to help more practically understand how stakeholders’ pressures affect the contingency release process, the work is supplemented with a comparison of the model case-scenarios with the three actual case projects that were used in developing the model and making some of its assumptions. All three projects are DB contracts reimbursed based on a target price, with sharing of savings and right for the owner to request improvements using the shared released savings. Apart from ease of data collection, these specific case studies are selected due to their alignment with the four simulation case-scenarios previously explained. Such a demonstration helps draw practical implications of the study. A summary version of the following discussion is presented in Table 2.

The first case-scenario simulation can be easily compared to the healthcare facility constructed in Italy. Here, a proactive predisposition of the project team to propose and implement substantial design and procurement improvements to the facility led to major profits during the final construction phase. Improvements were made through the usage of savings created from value engineering options. At that time, the company was running quite well on the stock market and there was no need to release early profit from that project. The focus of senior management was then more on quality improvements that might help make profit on a later stage. This is an aggressive approach comparable to simulation scenarios 1 and 2 aimed at improving the constructed facility.

The second simulation applies to the Turkish bridge case project, where a demanding owner requested the contractor to undergo an important redesign of the construction technique to produce savings that could be used to build some extra infrastructure for connection of the bridge to the local road network. This allowed the owner to get added work within the allocated public budget. However, this change of design strategy could not allow the DB contractor to be confident about the future cost performance of the project. Eventually, the project experienced significant cost overrun that had to be recovered via the usage of the remaining procurement and construction phases' contingency. In turn, very little profit was net out of that originally planned. This case project is comparable to simulation scenarios 3 where high owner's pressure is complimented by equally cooperating PM.

Finally, Scenario #4 is a good approximate replication of what happened to the Peruvian hydropower plant project. For that project, based on both the owner and senior management pressures to obtain early benefits from the project, the original engineering contingency was fully released because no extra design efforts were carried out and the owner did not order for extra works with their share of savings. However, during the procurement and construction phases, several risk events occurred that required the usage of the remaining contingency. Eventually, the project closed out with a much lower level of profit than expected.

Table 2. Summary version of practical case projects

Discussion and Implications

PMs look for policies that improve project profitability under uncertain conditions of risk and seek for risk management and project control practices that combine project robustness with the ability to perform well across a range of uncertain conditions (Lyneis and Ford 2007). The proposed model is a contribution to respond to this challenge and an attempt to help improve the way the contingency budget process is managed and understand how it impacts on the project outcomes based on different strategic options of PRM policy.

Moreover, the model introduces the multiple influences of the main project participants into the problem, and suggests that the PM should activate different PRM and contingency management policies based on the combination of often conflicting pressures to either do preventive risk-mitigating facility improvements or releasing the remaining contingency as savings.

In particular, it is suggested that a viable strategy that maximizes profitability is for the PM to proactively engage into substantial project improvements and added design flexibility at the beginning of the engineering stage in order to limit the late influences of the owner, who will find herself satisfied with the early improvements, and then still allow for a late disclosure of profit under the increasing pressure of senior managers. Moreover, this proactive project management strategy is likely to produce the same profit level as an opposite conservative strategy that would seek to maximize profit at the beginning via savings created with an optimized engineering, reduced constructive design cost estimate and cheaper procurement.

Usually, PMs can choose between better performance with fragility, as the conservative strategy suggests, or lower performance with robustness, as an aggressive contingency management strategy provides (Repenning 2000). However, the influence model proposed in this paper suggests that the two strategies cumulate the same level of profit performance so that the aggressive strategy may prove itself to be the recommended tradeoff for managing the contingency budget process along the project development. According to the classification of PRM approaches by Pich et al. (2002), the aggressive contingency management policy is an instructionist strategy that spends the contingency budget according to plans established from the outset combined with some flexibility to adapt and learn from unforeseen events. In other words, the preventive strategy can help achieve a balance between control for managing risk that has been identified and enough contingency budget flexibility for dealing with later unforeseen events (Osipova and Eriksson 2013).

This work and associated lessons learnt originate both theoretical and practical implications.

From a research perspective, this paper is a first contribution to analyze the stakeholders' behavior into the contingency management decision making process with a systemic approach. In particular, it integrates a previous SD model with the stakeholders' influences and enforcements on the PM's decisions on how to use the excess contingency, so that it stimulates research around the effects of multiple decision makers on PRM practices and behaviors, and their associated impacts on project performance. It also engages researchers into the application of SD modeling and simulation in complex EPC projects and allows framing the application of contingency management models into phased projects. It also stimulates potential discussion around the dominance of preventive contingency management proactively-aggressive strategies versus reactively-conservative strategies.

For managers, owners and practitioners, this work is an opportunity to improve the knowledge around these PRM strategic options and to learn how to manage contingencies more effectively while developing their projects. In fact, it has been recognized that the key role of controlling cost contingency during the project execution is one of the main activities of the PM nowadays (Barraza and Bueno 2007). To help in this task, the model can then be used as a simulation-based decision support tool for PMs to test various case-scenarios and select the most desirable project risk response strategy (Zhang and Fan 2013), and plan or react to the influences that they are likely to receive on their projects while making decisions around the usage of the excess contingency. In turn, the model is suggested as a communication methodology for all involved participants to better manage risk contingencies in a shared way, to align the diverging interests in managing contingency accounts, and better integrating the perspective of the owner, project teams and senior corporate managers to improve impacts and project economic performance.

The model also bears some limitations inherent with its assumptions. First, it does not include other stakeholders in the influence models, such as investors, lending institutions and the involved communities that can have a large impact on the contingency usage patterns. Second, the owner's and senior managers' pressures are identified as theoretical variables ranging from 0 to 1, but no representation of the real risk factors and their associated perceptions is introduced into the model, including design, construction, financial, and context risks.

Conclusion

This work proposes a contingency management dynamic model that allows simulating the influences of the main stakeholders over the contingency budget management process and explores the behavior of the contingency accumulation and release over the phases of a DB project, in particular under the sequenced phases of EPC.

The model is suggested to apply not only as a simulation tool for contingency decision making, but also to act as a communication method between various stakeholders regarding their policies in complex situations such as contingency release and decision-influencing. The model seems fit for complex EPC projects in a variety of construction fields where projects are burdened by complex decision making structures, such as in large infrastructure, real estate, and petrochemical applications.

However, the model still needs to address some future research issues. On one hand, its performance in other complex project realms, such as information technology, manufacturing, services, etc. is yet to be tested. However, it is believed that the inbuilt sophistication will allow for seamless integration into these project types with minor modifications in the model.

On the other hand, an interesting extension would be to add more stakeholders, such as investors and lenders, as well as to introduce the originating risk factors that motivate the different managerial influences into the contingency release decision.

Acknowledgement

The authors are grateful to the anonymous company for availability and support to this study. The authors wish also to thank Mr. Luca Morra, graduate student from the M.Sc. Program in Engineering & Management at Politecnico di Torino for effective and passionate contribution to this work.

References

Baccarini, D. (2005). Understanding project cost contingency–A survey. In Conference Proceedings of the Queensland University of Technology (QUT) Research Week International Conference (pp. 4-8) <http://www.arcom.ac.uk/-docs/proceedings/ar2004-0105-0113_Baccarini.pdf>

Barraza, G. A., Bueno, R. A. (2007). Cost Contingency Management. Journal of Management in Engineering, 23(3), 140-146

Del Caño, A., Pilar de la Cruz, M. (2002). Integrated methodolody for Project Risk Management. Journal of Management in Engineering, 128(6), 473-485

Doloi, H. (2012). Empirical analysis of traditional contracting and relationship agreements for procuring partners in construction projects. Journal of Management in Engineering, 29(3), 224-235.

FIDIC, The FIDIC Contract Guide, 2000

Ford, D. N. (2002). Achieving multiple objectives through contingency management. Journal of Construction Engineering and Management, 128(1), 30-39

Gordon, C. M. (1994), Choosing Appropriate Construction Contracting Method, Journal of Construction Engineering and Management, 120(1), 196-209

Günhan, S., and Arditi, D. (2007). Budgeting owner's construction contingency. Journal of Construction Engineering and Management, 133(7), 492-497.

Harper, C., Molenaar, K., Anderson, S., and Schexnayder, C. (2014). Synthesis of Performance Measures for Highway Cost Estimating. J. Manage. Eng., 30(3), 04014005.

Idrus, A., Fadhil Nuruddin, M., and Rohman, M. A. (2011). Development of project cost contingency estimation model using risk analysis and fuzzy expert system. Expert Systems with Applications, 38(3), 1501-1508.

IPMA (2006). *IPMA Competence Baseline*. International Project Management Association, Nijkerk, The Netherlands

Kapsali, M. (2011). Systems thinking in innovation project management: A match that works. International Journal of Project Management, 29(4), 396-407.

Khamooshi, H., and Cioffi, D. F. (2009). Program risk contingency budget planning. Engineering Management, IEEE Transactions on, 56(1), 171-179.

Kutsch, E., and Hall, M. (2005). Intervening conditions on the management of project risk: dealing with uncertainty in information technology projects. International Journal of Project Management, 23(8), 591-599.

Kwakkel, J. H., and Pruyt, E. (2013). Using system dynamics for grand challenges: The ESDMA approach. In: Systems Research and Behavioral Science, JohnWiley

Lyneis, J. M., Ford, D. N. (2007). System dynamics applied to project management: a survey, assessment, and directions for future research. System Dynamics Review, 23(2/3), 157–189

Mak, S.and Picken D. (2000). Using risk analysis to determine construction project contingencies. Journal of Construction Engineering and Management, 126(2), 130-136

Miller, R., Lessard, D. (2001). Understanding and managing risks in large engineering projects. International Journal of Project Management, 19(8), 437–443

Mills, A. (2001). A systematic approach to risk management for construction. Structural survey, 19(5), 245-252

Mingers, J., and White, L. (2010). A review of the recent contribution of systems thinking to operational research and management science. European Journal of Operational Research, 207(3), 1147-1161.

Osipova, E., Eriksson, E. (2013). Balancing control and flexibility in joint risk management: Lessons learned from two construction projects. International Journal of Project Management, 31, 391-399

PMI (2009), Practice Standard for Project Risk Management, Project Management Institute, Newtown Square, PA

Repenning, N. (2000). A dynamic model of resource allocation in multi-project research and development systems. System Dynamics Review, 16(3), 173-212

Repenning, N. and Sterman J. D. (2001). Nobody ever gets credit for fixing problems that never happened: creating and sustaining process improvement. California Management Review 43(4), 64–88

Richardson, G. P. (2011). Reflections on the foundations of system dynamics. System Dynamics Review, 27(3), 219-243.

Seyedhoseini, Noori, S., Hatefi, M. A. (2009). An integrated methodology for assessment and selection of the project risk response actions. Risk Analysis, 29(5), 752-763

Sonmez, R., Ergin, A., and Birgonul, M. T. (2007). Quantitative Methodology for Determination of Cost Contingency in International Projects. Journal of Management in Engineering, 23(1), 35-39.

Sterman, J. D. (2000). Business Dynamics: Systems Thinking and Modeling for a Complex World, McGrawHill, New York

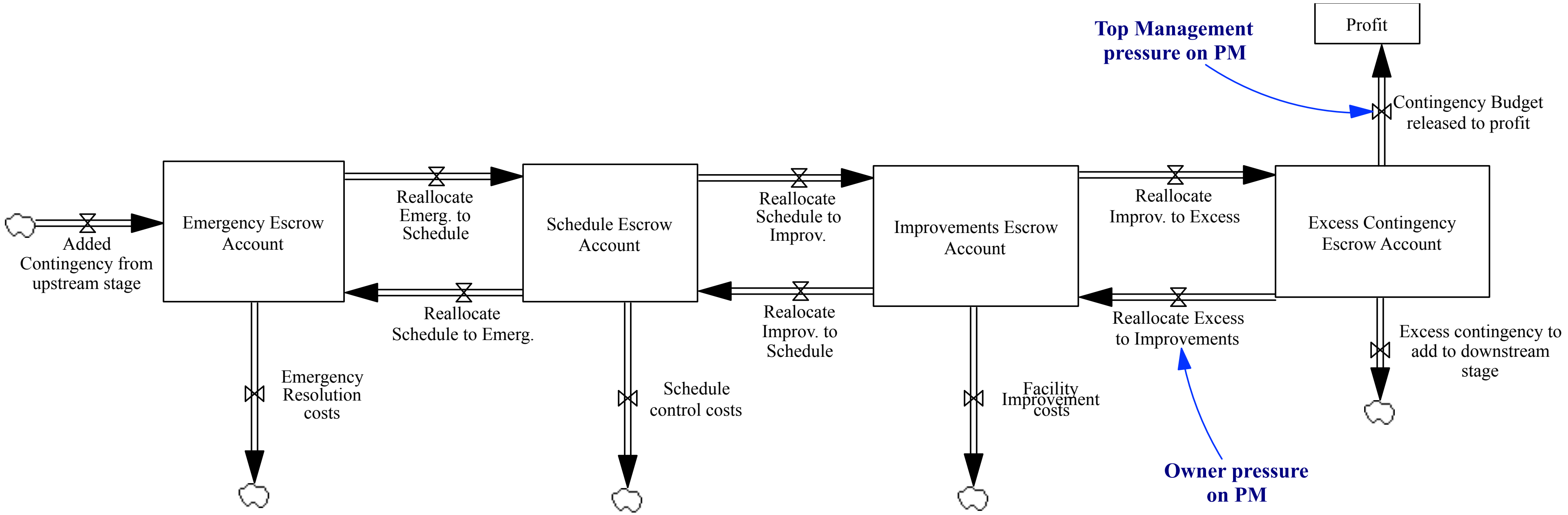
Thal Jr, A. E., Cook, J. J., and White III, E. D. (2010). Estimation of cost contingency for air force construction projects. Journal of Construction Engineering and Management, 136(11), 1181-1188.

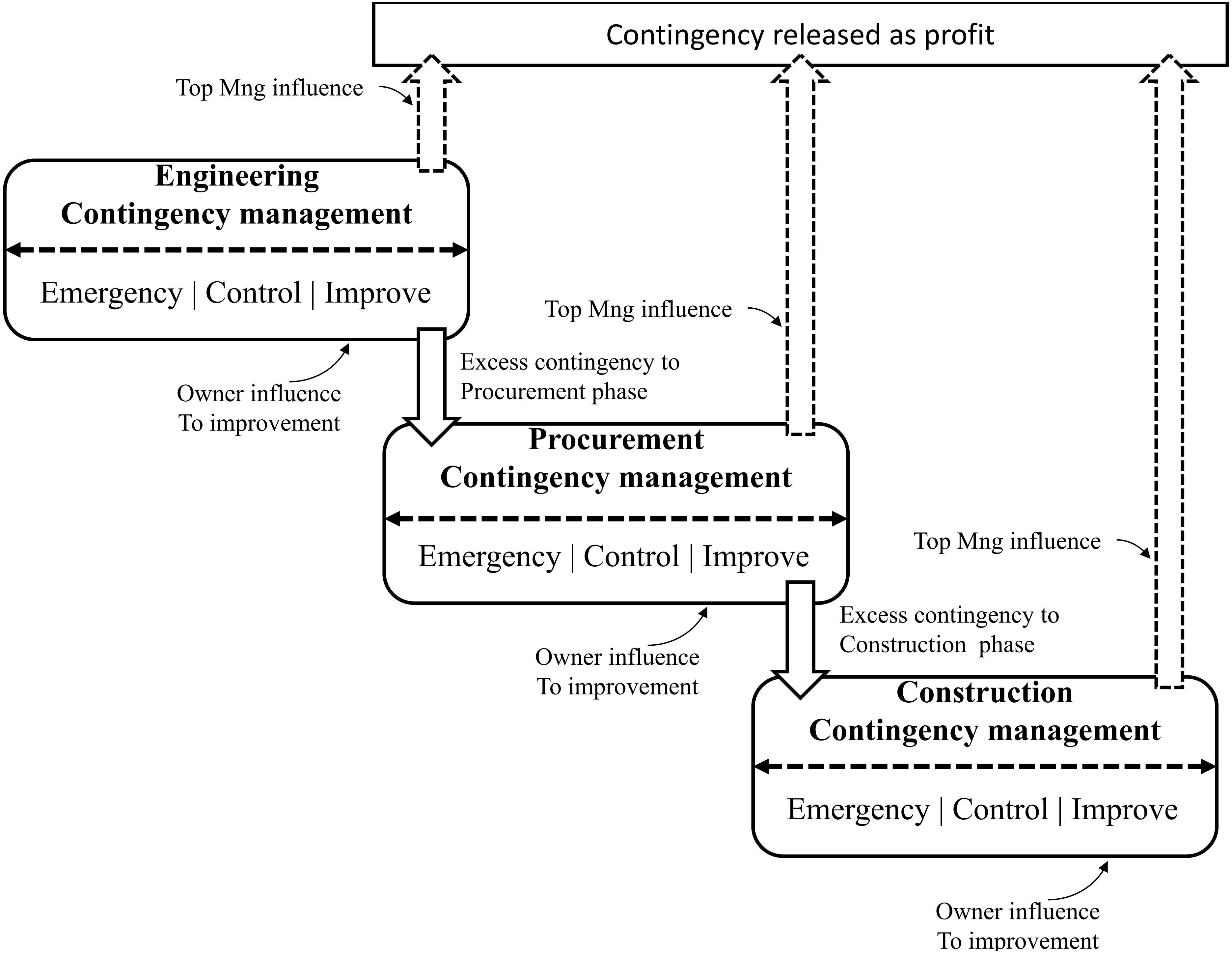
Tseng, C. L., Zhao, T., and Fu, C. C. (2009). Contingency estimation using a real options approach. Construction Management and Economics, 27(11), 1073-1087.

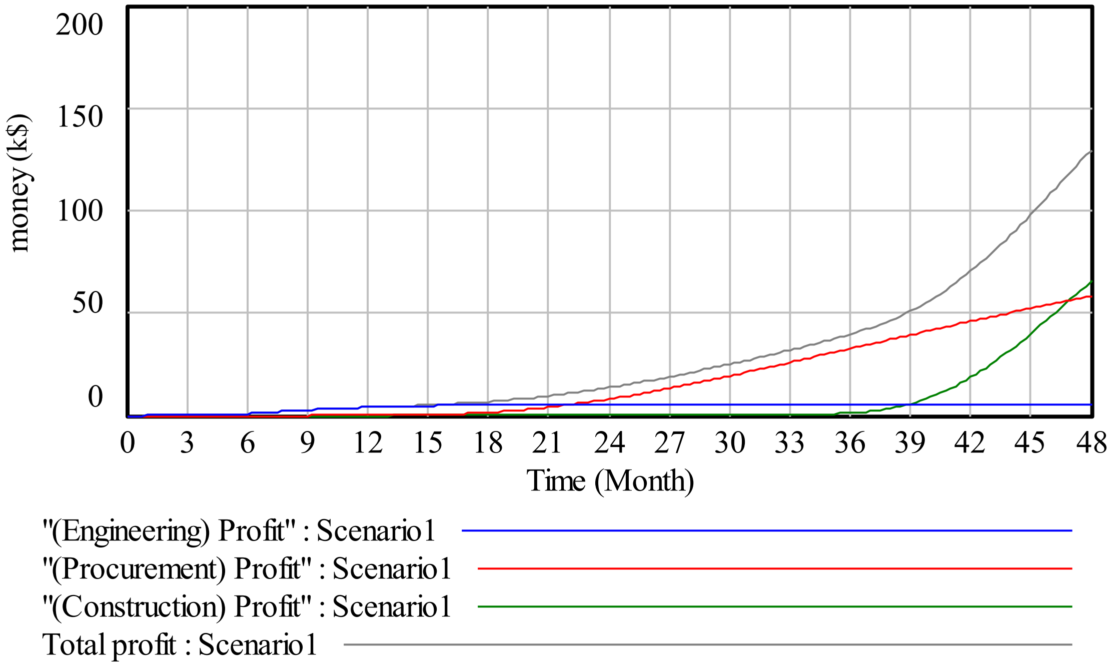
Xie, H., AbouRizh, S., Zou J. (2012). Quantitative Method for Updating Cost Contingency throughout Project Execution. Journal of Construction Engineering and Management, 138(6), 759-766

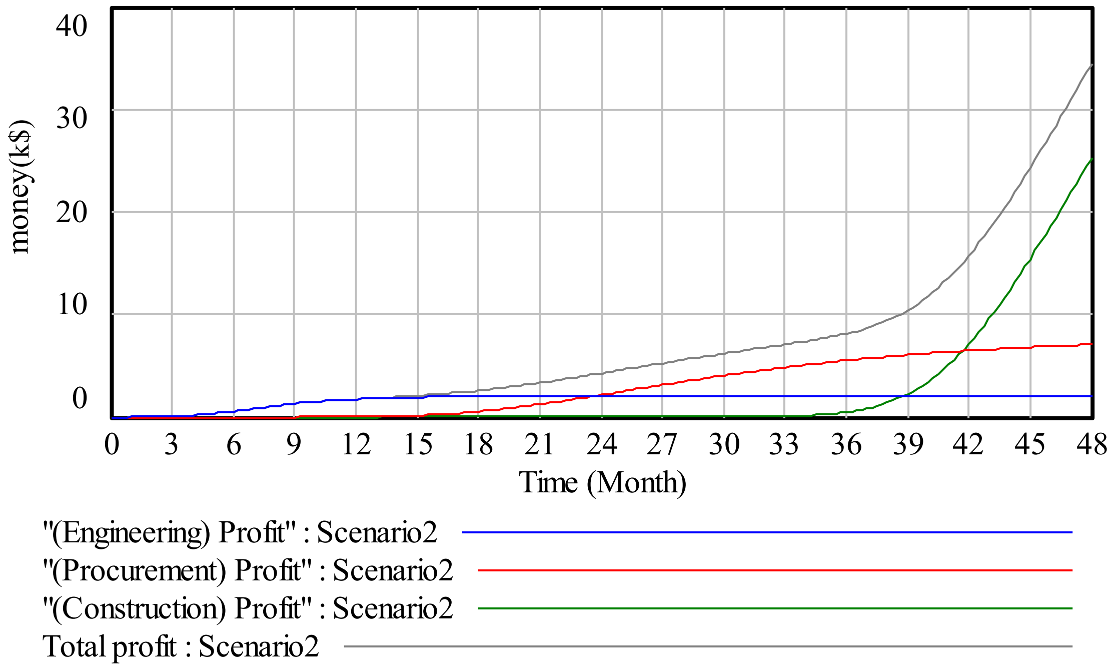
Weston, H. (1999). Turner Construction Company: Management Control Systems. Harvard Business School, HBS Case 9-190-128

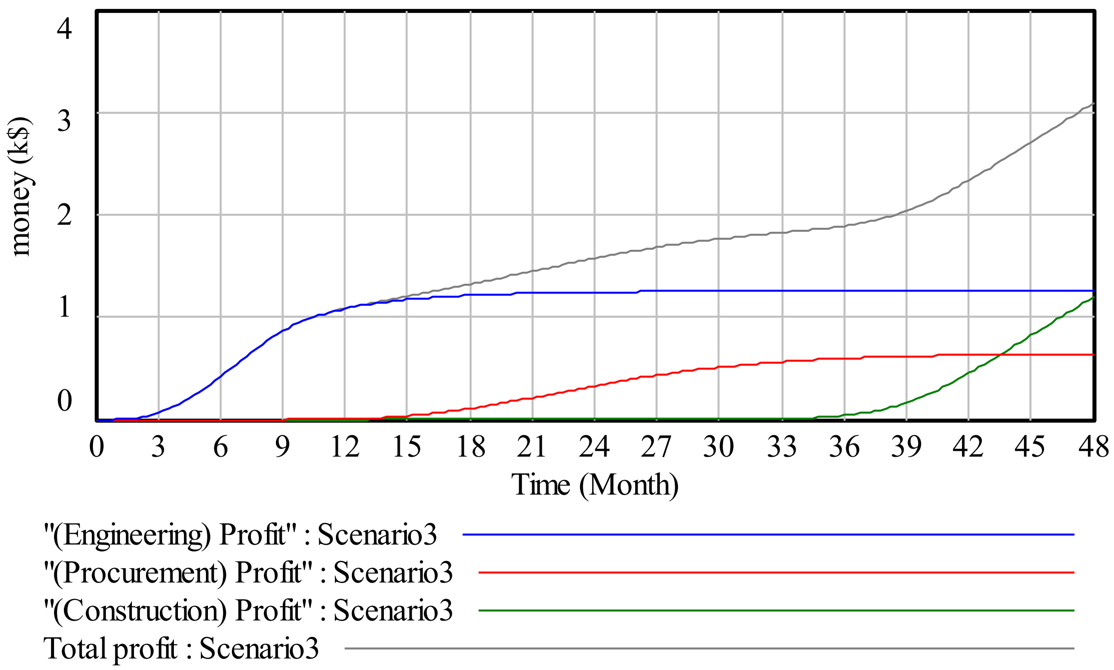
Zhang, Y., Fan, Z.-P. (2013), An optimization method for selecting project risk response strategies. International Journal of Project Management, 32, 412-422


Top Management pressure on PM
Profit
Contingency Budget released to profit
Emergency Escrow Account
Reallocate Emerg. to Schedule
Schedule Escrow Account
Reallocate Schedule to Improv.
Improvements Escrow Account
Reallocate Improv. to Excess
Excess Contingency Escrow Account
Added Contingency from upstream stage
Reallocate Schedule to Emerg.
Realocate Improv. to Schedule
Reallocate Excess to Improvements
Excess contingency to add to downstream stage
Emergency Resolution costs
Schedule control costs
Facility Improvement costs
Owner pressure on PM

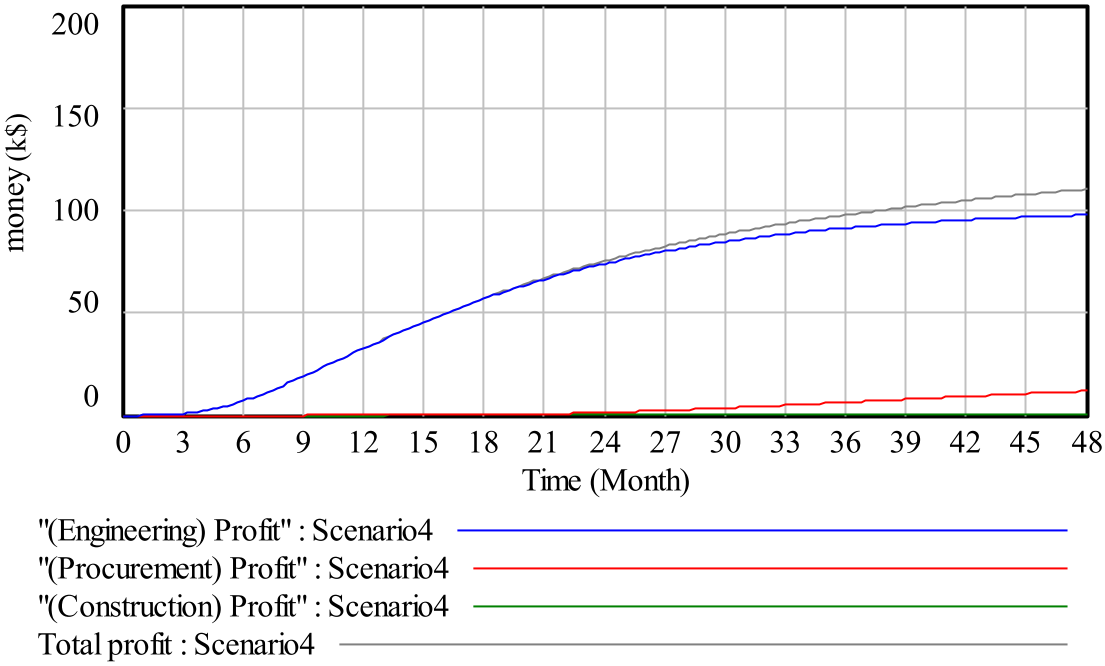

Contingency released as profit
Top Mng influence
Engineering
Contingency management
Emergency | Control | Improve
Owner influence
To improvement
Excess contingency to
Procurement phase
Top Mng influence
Procurement
Contingency management
Emergency | Control | Improve
Owner influence
To improvement
Excess contingency to
Construction phase
Top Mng influence
Construction
Contingency management
Emergency | Control | Improve
Owner influence
To improvement

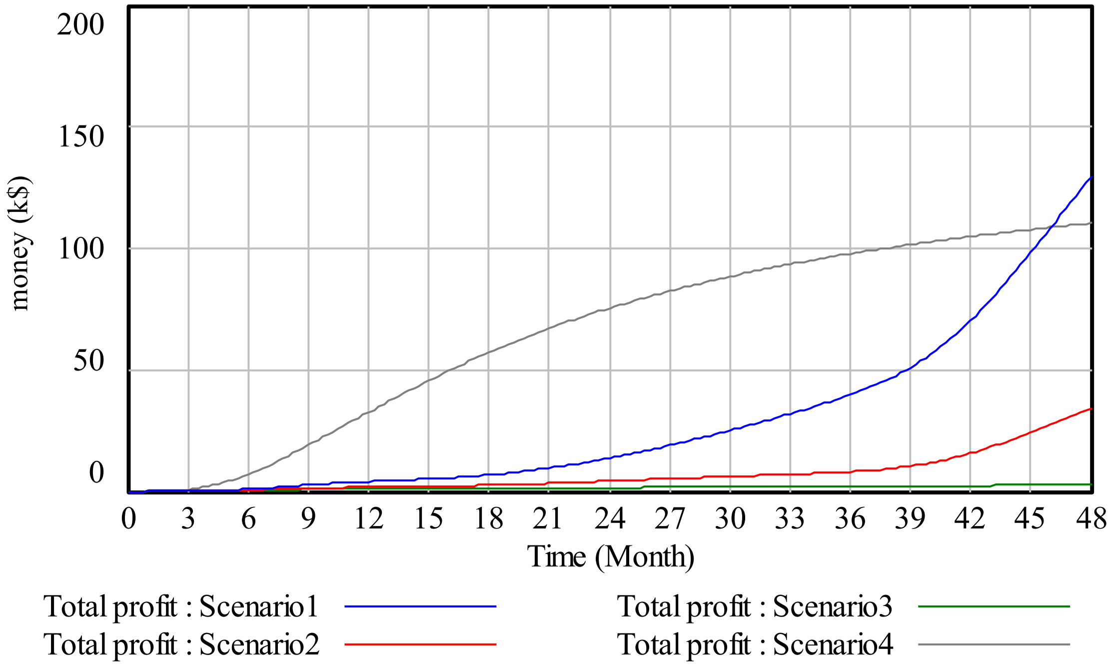

200
150
100
50
0
money (k$)
0
3
6
9
12
15
18
21
24
27
30
33
36
39
42
45
48
Time (Month)
"(Engineering) Profit" : Scenario1
"(Procurement) Profit" : Scenario1
"(Construction) Profit" : Scenario1
Total profit : Scenario1


40
30
20
10
0
money(k$)
0
3
6
9
12
15
18
21
24
27
30
33
36
39
42
45
48
Time (Month)
"(Engineering) Profit" : Scenario2
"(Procurement) Profit" : Scenario2
"(Construction) Profit" : Scenario2
Total profit : Scenario2



4
3
2
1
0
money (k$)
0
3
6
9
12
15
18
21
24
27
30
33
36
39
42
45
48
Time (Month)
"(Engineering) Profit" : Scenario3
"(Procurement) Profit" : Scenario3
"(Construction) Profit" : Scenario3
Total profit : Scenario3


money (k$)
200
150
100
50
0
0
3
6
9
12
15
18
21
24
27
30
33
36
39
42
45
48
Time (Month)
"(Engineering) Profit" : Scenario4
"(Procurement) Profit" : Scenario4
"(Construction) Profit" : Scenario4
Total profit : Scenario4


money (k$)
200
150
100
50
0
0
3
6
9
12
15
18
21
24
27
30
33
36
39
42
45
48
Time (Month)
Total profit : Scenario1
Total profit : Scenario2
Total profit : Scenario3
Total profit : Scenario4