IMPROVING INTEGRATED RISK ASSESSMENT AND MITIGATION MECHANISMS IN INVESTMENT PROJECT MANAGEMENT

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Abstract. Investment projects in emerging economies are exposed to several interacting risks at once: construction cost overruns, schedule delays, market volume and price volatility, input-cost inflation and currency depreciation. Conventional practice assesses and mitigates these risks one by one, using qualitative probability–impact matrices and a single deterministic net present value (NPV). This article proposes an integrated risk assessment and mitigation mechanism that links a risk register to a Monte Carlo NPV model, measures exposure with tail-risk indicators (VaR and CVaR), and selects mitigation measures as a portfolio rather than individually. A new indicator, the risk-adjusted mitigation efficiency (RAME), is introduced to rank measures by tail-risk reduction per unit of mitigation cost. The mechanism is tested on a stylised USD 40 million manufacturing project with 20,000 simulation runs. The planned deterministic NPV of USD 48.7 million turns into an expected NPV of only USD −2.7 million with a 58.2% probability of loss once risks are modelled. An integrated portfolio of four contractual and financial measures raises expected NPV to USD 13.8 million, cuts the probability of loss to 14.1% and improves $CVaR_5$ by USD 26.0 million. This exceeds the sum of the individual effects by 16.7%, which shows that the interactions between mitigation measures matter.

Keywords: investment project, risk management, Monte Carlo simulation, conditional value-at-risk, risk mitigation, project finance, net present value, emerging markets.

Investment projects are the main channel through which capital accumulation

turns into productive capacity, yet their record of delivering on plan is poor. In a database of more than 16,000 projects, Flyvbjerg and Gardner (2023) find that only 47.9% were delivered on budget, 8.5% on budget and on time, and just 0.5% on budget, on time and with the planned benefits. Earlier studies of large infrastructure projects show the same systematic pattern of cost overruns and benefit shortfalls (Flyvbjerg, 2014). Kahneman and Lovallo (1993) trace much of this to the "inside view": planners build a single optimistic scenario and treat it as the expected outcome. This problem is especially acute in emerging economies, where projects carry additional macroeconomic risks such as exchange-rate depreciation, input-price inflation and thinner markets for long-term hedging. Uzbekistan is a relevant example. Its industrial policy aims to raise the share of industry in GDP and expand high value-added production by 2030, which requires a large pipeline of greenfield investment projects, many of them with foreign participation. For such projects, the gap between the approved feasibility study and actual performance has direct consequences for lenders, investors and the state budget.

Project risk management standards such as ISO 31000:2018 and the PMBOK Guide (PMI, 2021) describe the process of identifying, analysing, treating and monitoring risks. In practice, however, three weaknesses persist: risks are scored qualitatively and in isolation; the financial model remains deterministic; and mitigation measures are chosen one by one, without testing how they interact. The **aim of this article** is to propose an integrated mechanism that removes these weaknesses, and to test it quantitatively on a stylised investment project.

The integrated mechanism. The proposed mechanism consists of five stages supported by a governance layer and a set of contractual and financial instruments (Figure 1). Its key difference from the standard process lies in stages 3 and 4. Risk exposure is measured on the project's NPV distribution, not on separate risk scores, and mitigation measures are evaluated jointly by re-simulating the whole project.

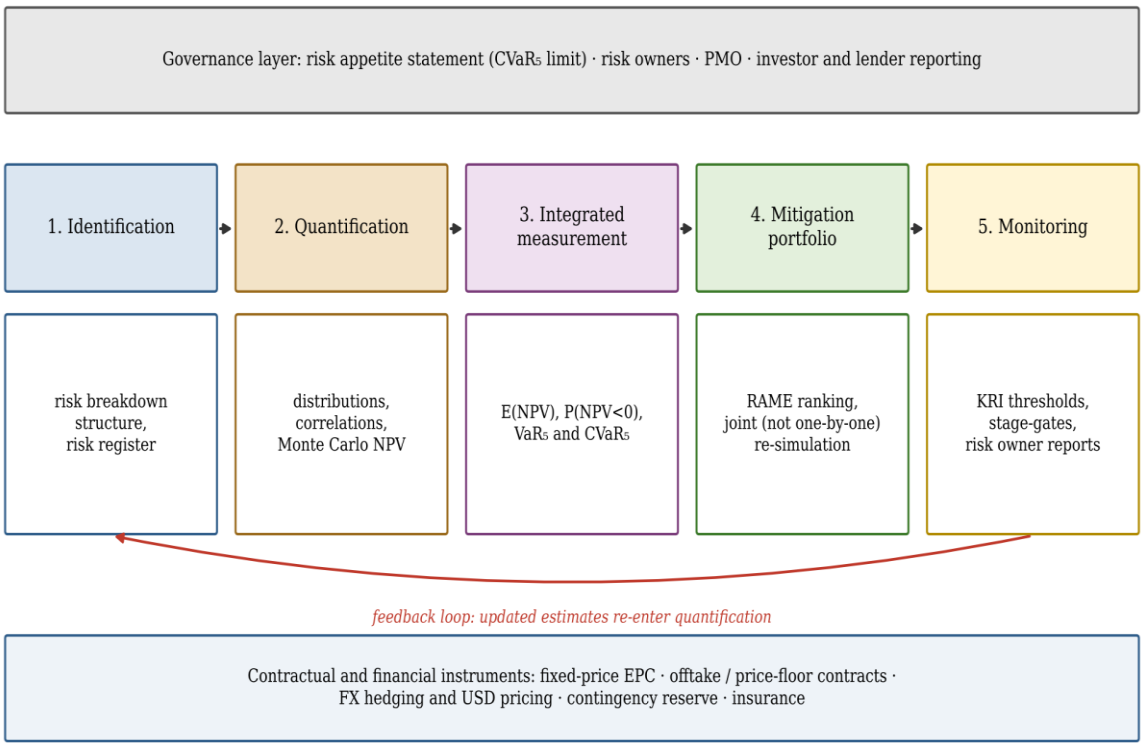


Figure 1. Integrated risk assessment and mitigation mechanism for investment projects

Risk measures. For each scenario the model reports the expected NPV, E(NPV); its standard deviation; the probability of loss, P(NPV < 0); VaR_5, the 5th percentile of the NPV distribution; and $CVaR_5$, the mean NPV in the worst 5% of outcomes. A project's risk appetite is stated as a minimum acceptable $CVaR_5$.

Risk-adjusted mitigation efficiency. To rank mitigation measures, we propose the risk-adjusted mitigation efficiency indicator:

$$RAME_m = (CVaR_5 \text{ with measure } m - CVaR_5 \text{ baseline}) / PV(\text{cost of measure } m).$$

RAME shows how many dollars of tail-risk reduction a measure buys per dollar of its present-value cost. A value above 1 means the measure reduces the average loss in the worst 5% of outcomes by more than it costs. We also define the portfolio synergy coefficient as the ratio of the $CVaR_5$ improvement from the integrated

portfolio to the sum of the individual improvements. A value above 1 indicates that the measures reinforce each other.

The mechanism is tested on a stylised greenfield manufacturing project with an investment of USD 40 million, a 10-year operating horizon, a 14% discount rate, base annual revenue of USD 54 million, fixed operating costs of USD 6 million, variable costs of 50% of base revenue at full volume, a 15% profit tax and a 15% residual value. Six risk factors are modelled with distributions that reflect typical conditions for projects in emerging markets (Table 1). The parameters are illustrative assumptions made by the author, not data from a specific enterprise. Each scenario is simulated with 20,000 runs using the same random seed, so differences between scenarios reflect the measures, not sampling noise.

Table 1.

Risk factors and their modelled distributions

Risk factor	Baseline distribution	Effect of the relevant mitigation measure
Capex overrun	Triangular (−5%; +10%; +45%)	M1 fixed-price EPC: (−3%; +4%; +12%), 3% contract premium
Construction delay	0 / 1 / 2 years with p = 0.55 / 0.30 / 0.15	M2 stage-gate and PMO: p = 0.75 / 0.20 / 0.05, USD 0.12 m per year
Sales volume	Triangular (60%; 90%; 105%) of capacity	M3 offtake agreement: (80%; 92%; 102%)
Sales price	Normal (1.00; σ = 0.08)	M3 offtake agreement: σ = 0.04, 2% price discount
Operating cost	Triangular (0.95; 1.00; 1.20)	Not mitigated (retained risk)
FX depreciation	Triangular (0%; 8%; 20%) per year on the local-currency revenue share of 50%	M4 FX hedge / USD pricing: local share 20%, USD 0.25 m per year

When all risk factors are set to their planned values (no overrun, no delay, full volume, planned prices and costs, stable exchange rate), the project shows a

deterministic NPV of USD 48.7 million. Once risks are simulated, however, the expected NPV falls to USD −2.7 million and the probability of loss is 58.2% (Table 2). A project that looks highly attractive in a single-scenario feasibility study is in fact marginal. This is the quantitative form of the optimism bias described by Kahneman and Lovallo (1993) and Flyvbjerg (2014). Spearman rank correlations between the risk factors and NPV show which factors drive the dispersion. Sales price accounts for 45.9% of the explained variance, followed by volume (16.0%), construction delay (14.4%), operating cost (9.6%), FX depreciation (9.2%) and capex overrun (4.9%). Commercial risks therefore matter more than construction risks, although construction risks receive most of the attention in conventional project appraisal.

Table 2.

NPV risk profile by mitigation scenario, USD million (20,000 runs)

Scenario	E(NPV)	SD	P(NPV<0), %	VaR_5	$CVaR_5$	RAME
Baseline	−2.75	18.96	58.2	−31.46	−37.81	—
M1 Fixed-price EPC	0.95	18.55	50.8	−26.91	−32.89	3.52
M2 Stage-gate and PMO	−0.46	19.20	53.1	−30.37	−36.91	1.43
M3 Offtake agreement	−1.14	14.22	54.0	−23.69	−28.67	1.91
M4 FX hedge / USD pricing	5.44	19.30	41.4	−24.15	−30.45	5.64
Integrated (M1–M4)	13.80	12.60	14.1	−6.87	−11.77	3.21

Each measure improves the tail of the distribution, but in different ways. FX hedging and USD pricing (M4) gives the largest gain in expected NPV (+8.2) and the highest RAME (5.64), because depreciation steadily erodes the value of local-currency revenue throughout the operating period. The offtake agreement (M3) gives the largest single improvement in $CVaR_5$ (+9.1) and cuts the standard deviation by a quarter, since it acts on the dominant price risk. However, the price discount makes it costly, so its RAME is only 1.91 and its expected NPV slightly decreases. A fixed-price EPC

contract (M1) is highly efficient (RAME 3.52), whereas stage-gate control (M2) brings a modest gain at low cost. Ranking by expected NPV alone would therefore place M3 last, although it is the strongest tail-risk instrument. This illustrates why the choice of risk measure determines the choice of mitigation.

The integrated portfolio. Applying the four measures together raises expected NPV to USD 13.8 million, reduces the probability of loss from 58.2% to 14.1% and lifts $CVaR_5$ from −37.8 to −11.8 (Figure 2). The total $CVaR_5$ improvement of USD 26.0 million exceeds the sum of the individual improvements (USD 22.3 million) by 16.7%, so the synergy coefficient is 1.17. The reason is the nonlinearity of the project's cash flows. When volume and price are stabilised, lower capex and a stable currency translate more reliably into positive cash flow, so each measure works on a less fragile base. With a portfolio cost of USD 8.1 million in present value, the integrated RAME is 3.21.

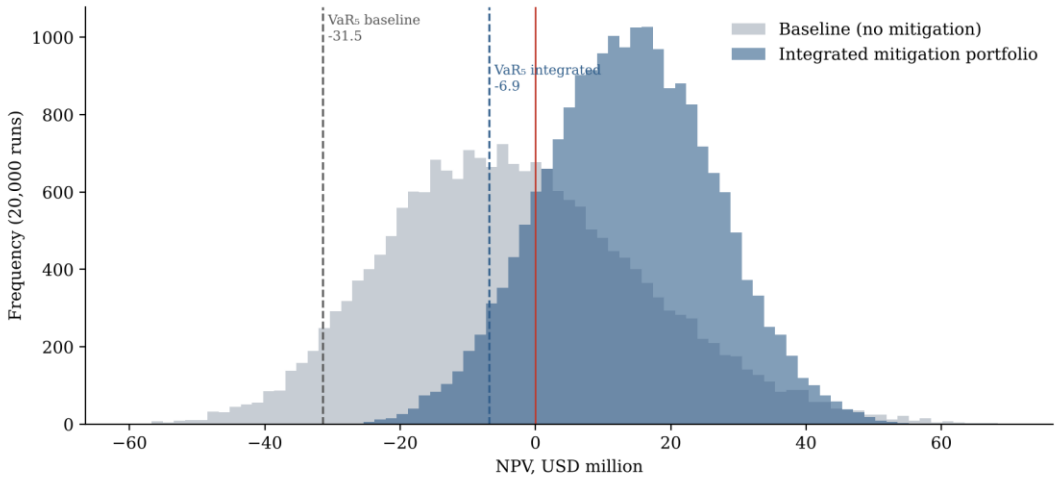


Figure 2. NPV distribution before and after the integrated mitigation portfolio

The results support the view of Miller and Lessard (2001) that project value is created by shaping risks through contracts and governance, not only by forecasting them. In the case analysed, three of the four measures are contractual or financial instruments that cost little relative to the project, yet they move the project from a

likely loss to a likely gain. Hertz (1964) made a similar point about the value of simulation over point estimates. Our results extend it: simulation is needed not only to appraise the project but also to choose and combine the mitigation measures. Three practical implications follow. First, feasibility studies and bank appraisals should report the NPV distribution and CVaR alongside the deterministic NPV. A single figure of USD 48.7 million would have hidden a 58% probability of loss. Second, mitigation measures should be approved as a package and tested by joint re-simulation, because the portfolio effect is larger than the sum of the parts. Third, the dominance of price and volume risk suggests that, for export-oriented projects in emerging markets, commercial contracts and currency management deserve at least as much attention as construction contracts. The study has limitations. The project parameters and distributions are stylised, so the numerical results illustrate the mechanism rather than forecast any real project. The risk factors are modelled as independent, while in practice depreciation, inflation and demand are often correlated. Positive correlations would widen the baseline tail and probably increase the value of integrated mitigation. Managerial flexibility, such as the option to defer or expand, is not valued explicitly. Extending the model with correlated risks and real options, and calibrating it on actual project data from Uzbek investment programmes, are directions for further research.

The article proposes an integrated mechanism for risk assessment and mitigation in investment project management. The mechanism connects a risk register to a Monte Carlo NPV model, measures exposure through E(NPV), P(NPV < 0), VaR_5 and $CVaR_5$, and selects mitigation measures as a jointly tested portfolio, all within a governance layer that sets a formal risk appetite. Two new indicators are introduced: the risk-adjusted mitigation efficiency (RAME), which ranks measures by tail-risk reduction per unit of cost, and the portfolio synergy coefficient. Testing on a stylised USD 40 million project showed that a deterministic NPV of USD 48.7 million corresponds to an expected NPV of USD −2.7 million and a 58.2% probability of loss once risks are

modelled. An integrated portfolio of a fixed-price EPC contract, stage-gate control, an offtake agreement and FX management raises expected NPV to USD 13.8 million and reduces the probability of loss to 14.1%. Its effect on CVaR$_5$ is 16.7% larger than the sum of the individual effects. For project sponsors, lenders and public investment agencies, the main recommendation is to replace single-scenario appraisal and one-by-one risk treatment with distribution-based appraisal, an explicit CVaR limit, and portfolio-based selection of mitigation measures.

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